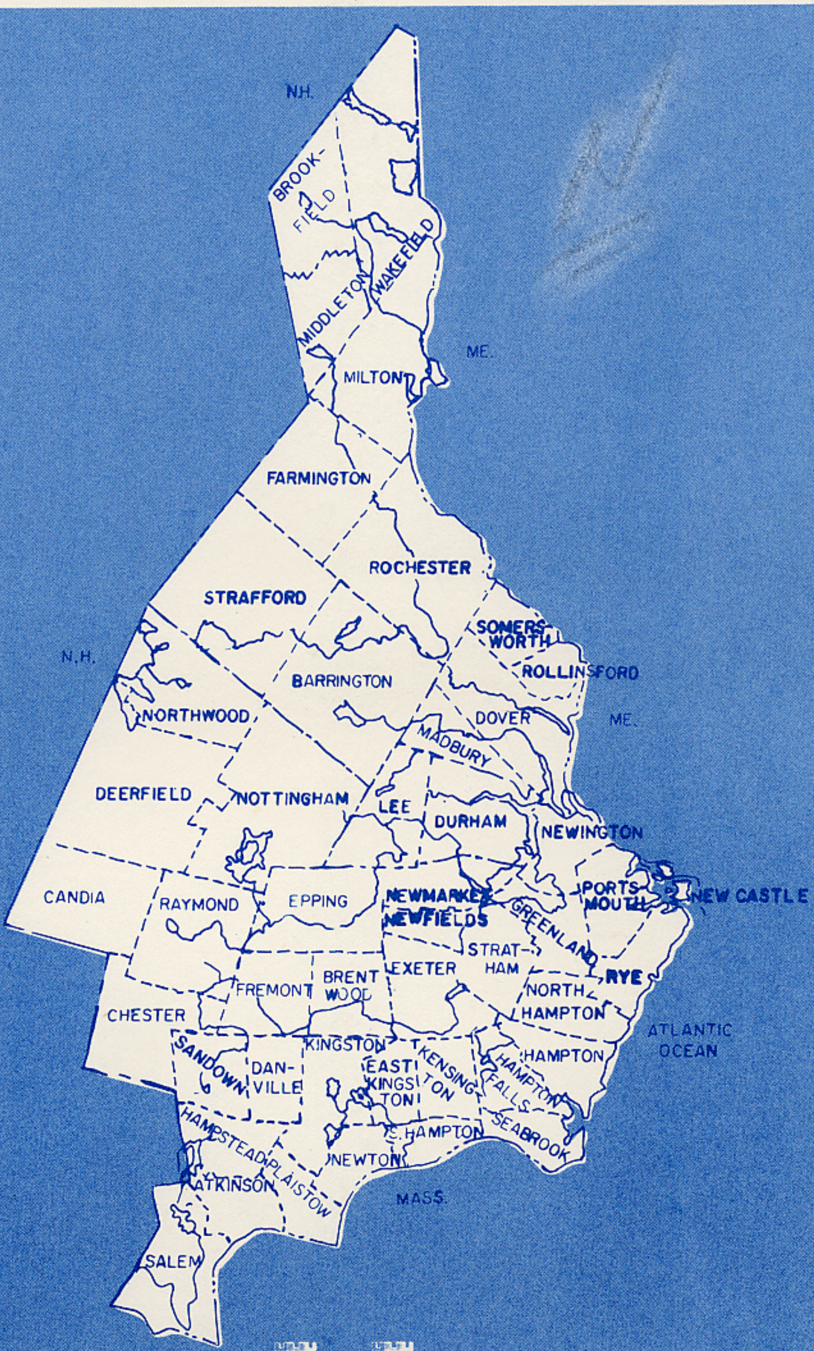
SOUTHEAST NEW HAMPSHIRE WATER SUPPLY STUDY

ESTIMATED DEMANDS AND RESOURCE AVAILABILITY



DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION

CORPS OF ENGINEERS

JULY 1976

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ERRATA

1. Pg. 51 - last sentence, 1st paragraph 0.75 cfs should read 9.5 cfs.

2. Tables IV-1 and IV-2, and descriptions of Raymond and Rollinsford, page 67, should be changed to reflect the following omissions: (1) purchase of Manchester Land and Gravel Company's well (estimated safe yield greater than 1.00 mgd) by Raymond; and, (2) the existence of a 1 mgd water treatment plant on the Salmon Falls River which serves Rollinsford.

3. Item C, pg. 2 should read Strafford-Rockingham Regional Council, Lakes Region Planning Commission, Central New Hampshire Regional Planning Commission, and Southern New Hampshire Planning Commission.

4. Pg. 29 - 1st sentence, third paragraph - the 527 mgd cooling water is salt water, and is cited for magnitude comparisons only.

SUMMARY

This report, undertaken at the request of the New Hampshire Water Supply and Pollution Control Commission, the New Hampshire Office of Comprehensive Planning and the New Hampshire Water Resources Board, was performed under the authority contained in Section 22 of the Water Resources Development Act (PL 93-251).

The need for an integrated study of the water resources of the seacoast region of New Hampshire was addressed in the Draft Plan of Study, Southeast New Hampshire Water Supply Study, dated July 1975. The study area identified in that document included 47 communities covering an area of approximately 1,000 square miles of which 16 square miles lie in the Saco River Basin; 55 square miles within the New Hampshire Coastal Basin; 173 square miles within the Merrimack River Basin, and, 755 square miles within the Piscataqua River Basin. The 810 square miles which drain easterly to the coast (the Piscataqua and New Hampshire Coastal Basins) generate an average annual runoff of approximately 770 million gallons per day (mgd). However, many communities are now experiencing near capacity water demands, and anticipated population growth is expected to place even greater demands on the area's water resources. These near capacity demands, when seen in the light of the average annual runoff and the low flows recorded in the area's streams, point up the need for storage, greater reliance upon groundwater, or an integrated use of ground and surface water. Therefore, an assessment of all future water resource needs and capabilities must be initiated now so that all alternatives may be carefully studied and those portions selected that will evolve into a technically feasible, socially, economically and environmentally acceptable plan that can meet all of these needs in a timely fashion. This report, which addresses existing water supply source capabilities, future populations and water demands, and possible future groundwater potential and surface water storage sites, is a first step in the overall assessment that is required. Follow-up work on possible solutions to the problems is required and is expected to be performed in subsequent years.

The report discusses in detail the methodologies used to extrapolate the existing State population estimates for the 47 communities within the study area from the year 2000, where the State's estimates end, to the year 2020 which is this report's time frame. Individual community population estimates for the years 1980, 1990, 2000, 2010 and 2020 are given

in the report, and the region is expected to grow from its reported 1970 population of 188,289 to the estimated 2020 population 402,160.

Three techniques of estimating domestic demands were used to develop a range of future demands and a rationale, based upon community population densities was developed to determine at what stage of development a community would initiate a public water supply system. This was an important step because 25 of the 47 study area communities are not now presently served by a public water supply system. The criterion used - 0.35 persons per community land area - indicates that 12 of these 25 communities may initiate public water supply systems by the end of this study's time frame (the year 2020).

A technique for estimating future publicly supplied industrial water demands was also formulated and used to calculate future industrial usage. The future industrial usage accounts only for expansion of existing industry; no attempt was made to forecast the types of industry which the area could attract except to address the possible effects which an oil refinery may have on the area. The possible oil refinery sites were designated by the Governor prior to this study. Overall, the total publicly supplied water demand is expected to rise from 16.9 mgd average daily water usage in 1974 to 49.8 mgd average daily water usage in 2020. The served population is estimated to increase from 173,366 to 374,615 in the same time period.

An estimate of total groundwater availability within the region was made based on existing report data. Because of the widely divergent sources and this associated reliability, more conservative estimates were made for some areas than others. These groundwater locations are indicated on a map of the area, and possible community total groundwater quantities were calculated.

Major streams within the study area were analyzed to determine the possibility of using run of the river flows for water supply purposes. No major stream in the area has a sufficiently high flow to allow for a large run of the river development, therefore storage sites, as reported by the Soil Conservation Service, were also mapped and descriptions tabulated.

Finally, a comparison between existing public water supply source capabilities and estimated future demands and existing source capabilities augmented by all of the estimated groundwater available and estimated future demands were made. Both of these comparisons show that additional source augmentation, whether by in-basin surface water storage or inter-basin transfers, is required if the region is to meet its future water requirements. The estimated regional deficits are summarized in the table below:

Regional, Publicly Supplied Water Deficits
(Figures are in million gallons per day)

	1980		1990		2000		2010		2020	
	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day
Existing Sources	2.6	16.8	5.7	29.4	10.2	42.5	14.9	55.6	19.9	67.2
Existing Sources & All Potential Groundwater	1.4	9.3	2.7	15.9	4.2	23.9	6.2	34.5	8.5	44.7

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I. INTRODUCTION

A. Background

The need for an integrated cooperative study of the water resources of the seacoast area of southeastern New Hampshire was addressed in the Draft Plan of Study, Southeastern New Hampshire Water Supply Study, dated July 1975. In summary, the forty seven (47) communities which comprise the study area have had a population increase from 94,296 in 1940 to 188,289 in 1970 or almost an exact doubling in 30 years! Based on the population predictions currently available, it is estimated that the 1970 population will double again between the years 2010 and 2015. Thus, although the overall rate of increase is decreasing somewhat, the region as a whole can be characterized as a growth area. Also within the region, some communities are presently experiencing an average daily water demand rate near the estimated safe yield of their source, or sources, of supply. The significant anticipated increases in population therefore coupled with the near capacity demands now being experienced, will place even greater demands on the water resources of the region. Therefore, in order to insure that the water resources will be available, for all of the various future needs, it is imperative that regional, and possible inter-regional, planning be initiated now so that all of the various alternatives may be studied, selected or discarded as the case may be, and an overall plan be evolved which will allow for growth compatible with use of the water resource.

B. Authority

At the request of the New Hampshire Water Supply and Pollution Control Commission, the Office of Comprehensive Planning and the Water Resources Board, the New England Division of the Corps of Engineers has been asked to assist the State of New Hampshire in a cooperative investigation of the regional water supply needs of the seacoast area. Provisions for assistance by the Corps in such a joint venture are contained in Section 22 of the Water Resources Development Act (PL 93-251). Section 22 of PL 93-251 reads as follows:

"(a) The Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with any State in the Preparation of comprehensive plans for the development, utilization, and conservation of the water and related resources of drainage basins located within the boundaries of such State and to submit to Congress Reports and recommendations with respect to appropriate Federal participation in carrying out such plans.

(b) There is authorized to be appropriated not to exceed $2,000,000 annually to carry out the provisions of this section except that not more than $200,000 shall be expended in any one year in any one State."

C. Study Area

The study area, Plate 1, includes a total of 47 communities consisting of approximately 1,000 square miles lying in the southeastern part of New Hampshire. All communities which fall within the Salmon Falls River Basin, the Piscataqua River Basin, the Coastal River Basin and the communities of Atkinson, Hampstead, Newton, Plaistow and Salem in the Merrimack River Basin were included in the investigations. The cities and towns studied are within the boundaries of the Strafford Regional Planning Commission, the Southern Rockingham Regional Planning Commission and the Central New Hampshire Regional Planning Commission.

D. Scope of Work

This report has the following study objectives:

1) Develop population projections, to the year 2020, for each community within the study area.

2) Develop a methodology for estimating which communities, of those not presently served by a public water supply system, will be served and the time period for initiation of that service.

3) Develop a methodology for determining the populations served by public supply systems in the various communities.

4) Develop domestic gallon per capita per day (gpcd) rates for communities which presently have, or are anticipated to have public water supply systems.

5) Estimate future industrial demands which will be supplied from public water supply systems.

6) Compare existing safe yields of the various systems with the estimated future demands to determine the adequacy of these systems.

7) Identify possible future groundwater sources within the study area.

8) Identify possible future surface water sources within the study area.

SOUTHEAST NEW HAMPSHIRE WATER SUPPLY STUDY

STUDY AREA

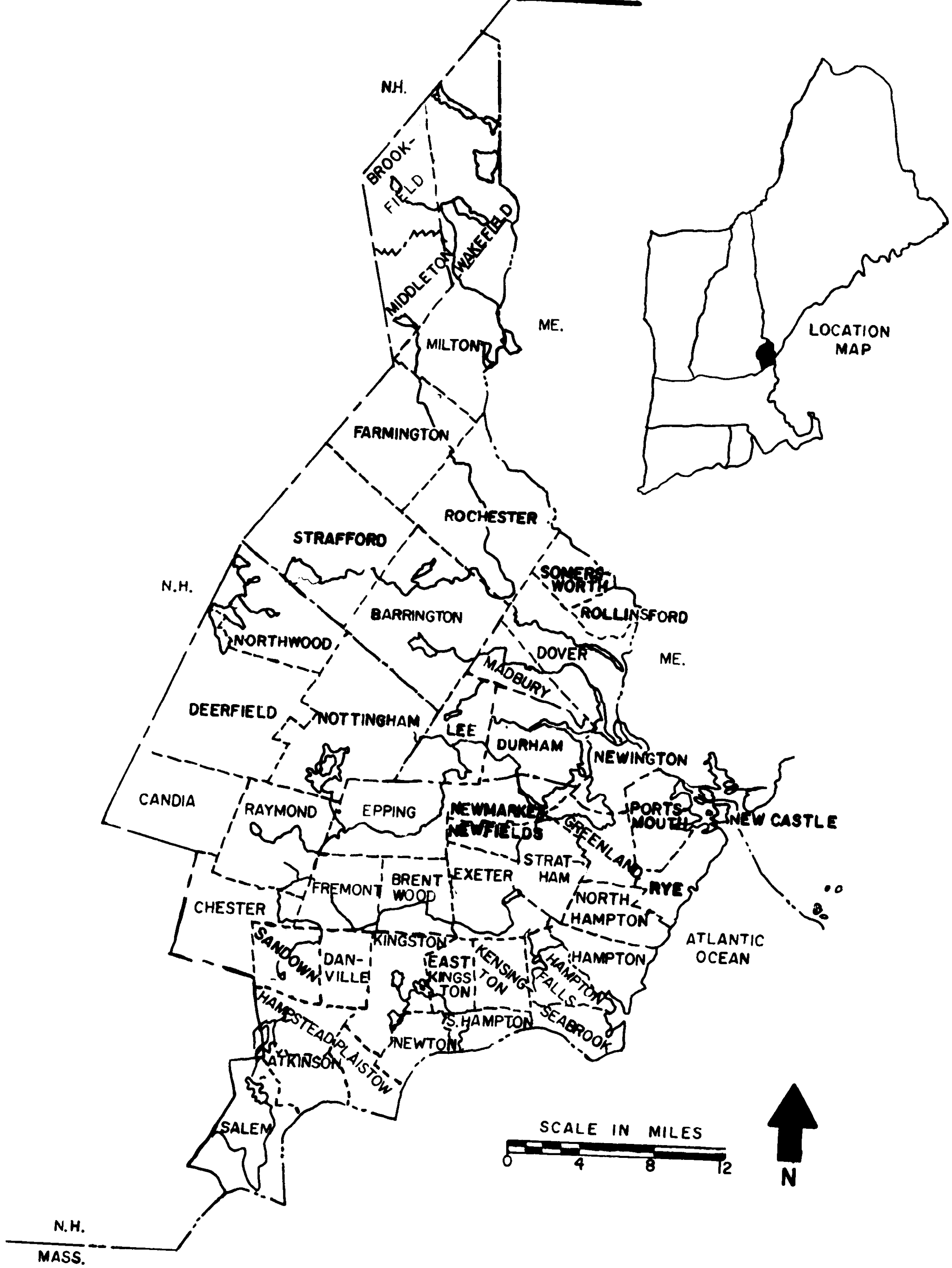

PLATE 1

II. WATER SUPPLY ASSESSMENT

A. Municipally Supplied Domestic Demands

1. Population Estimates

Estimates of future populations to the year 2000 for each of the 47 communities within the Study Area have been recently prepared by the New Hampshire Office of Comprehensive Planning (OCP) and these figures were used as the basis for population forecasts. These estimates varied significantly from earlier population predictions used in the Statewide Water Supply Study[1] conducted during the late 1960's. This difference between the two estimates may result from the 1970 Census (which the earlier statewide study did not have) and the lower birth rate (Series E) which is now used for such projections. Because this report's time frame extends past the year 2000 to the year 2020; and because comparisons between the OCP population predictions and those of the Statewide Water Supply Study were negated by the different data bases, an entirely new projection had to be established for the period 2000-2020.

In order to estimate population figures for 2000-2020, the OCP estimates for this study area were divided into two groupings: one group consisting of those communities within the Primary and Secondary Zones as defined by the Coastal Zone Management Program; the second group consisting of the communities comprising the Tertiary Coastal Zone and three additional communities within the Southern Rockingham Regional Planning Agency. The total population predicted in 5 year increments from 1970 to 2000 for each group above was analyzed by various regression techniques. The mathematical model, which yielded the closest approximations to the population estimates provided, was then used to predict the total group population from the year 2000 to the year 2020. This analysis then formed the basis from which all community population estimates within the group were made. The percent of the individual community's estimated population to the group's total population for the years 1970 to 2000 were analyzed by various regression techniques. The analysis which yielded the closest approximations to these percentages became the predictive model for that community to the year 2020. The percentages for the years 2005, 2010, 2015, and 2020 were then calculated and these percentages were multiplied by the total group population figure to yield the predicted community's populations.

[1] Public Water Supply Study - Phase One Report, prepared for the New Hampshire Department of Resources & Economic Development by Anderson-Nichols & Co., Inc., May 1969.

The following examples are offered for clarification. The first example illustrates how the group total populations (specifically the Primary and Secondary Zone) were forecast to the year 2020 by trending the population predictions of the OCP from the year 2000 to the year 2020. The second example (specifically Northampton) illustrates the trending procedure used to estimate each community's percent population as compared with the group totals from the year 2000 to the year 2020.

The equation which analysis of the Primary and Secondary Zone total populations yielded was:

$y=95.346 + 2.222x - 0.004x^2$

where:

y=population, in thousands

95.346, 2.222 and -0.004 are constants determined by regression analysis

x=years (1970=0)

Table II-1 lists the results of this analysis. The equation which best fits the trending of the town of Northampton's population percentages was:

$y=1.635\,x^{0.417}$

where:

y=predicted percentage

1.635 and 0.417 are constants determined by regression analysis

x=years (1970=1)

Table II-1 also lists the results of this analysis.

Table II-2 lists the forty seven communities within the study area, the 1970 census population figure, the 1975 to 2000 OCP population estimates, and the population estimates for the years 2005 to 2020 calculated for this report.

The importance of the different population projections prepared over the years and their impact on the Study Area's future supply needs can be fully appreciated by inspecting Table II-3. This table lists the projected populations given in the statewide Water Supply Study and the Office of Comprehensive Planning/Corps of Engineers estimates.

TABLE II - 1

ILLUSTRATION OF POPULATION PREDICTION METHODS

Example \ Year	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
1. Primary & Secondary Zone Totals OCP	96,238	105,350	116,300	127,870	139,120	149,310	157,400				
Calc.	96,346	106,360	117,120	127,780	138,190	148,400	158,410	168,220	177,830	187,240	196,450
% Dif.	-0.11	-0.69	-0.70	0.70	0.67	0.61	-0.64				
2. North Hampton Pop.	3,259	3,410	4,910	6,540	8,000	9,340	10,540				
% of Group Total	3.38	3.21	4.19	5.12	5.79	6.29	6.65				
Calc. % of Group Total		3.20	4.27	5.06	5.70	6.26	6.75	7.20	7.61	8.00	8.36
Calc. Pop.		3,400	5,000	6,470	7,880	9,290	10,690	12,110	13,530	14,980	16,420

TABLE II-2

POPULATION PROJECTIONS FOR COMMUNITIES WITHIN THE STUDY AREA

Community	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Atkinson	2,291	3,000	5,670	7,460	8,910	9,910	10,580	11,320	11,970	12,610	13,250
Barrington	1,865	2,940	3,250	3,620	3,770	3,870	4,070	4,230	4,360	4,490	4,630
Brentwood	1,468	1,570	2,170	3,000	3,880	4,830	5,700	6,610	7,520	8,450	9,420
Brookfield	198	300	320	320	330	330	340	350	360	360	370
Candia	1,997	2,250	2,450	2,510	2,590	2,620	2,700	2,770	2,820	2,870	2,910
Chester	1,382	1,600	1,720	1,740	1,800	1,820	1,870	1,920	1,940	1,980	2,020
Danville	924	1,030	1,850	2,450	2,930	3,310	3,570	3,810	4,040	4,240	4,440
Deerfield	1,178	1,520	1,770	1,890	1,950	1,970	2,020	2,080	2,130	2,180	2,220
Dover	20,850	23,040	24,000	25,120	25,320	25,780	26,500	27,420	28,340	29,020	29,570
Durham	8,869	9,870	10,390	10,650	10,800	10,880	11,200	12,220	14,240	17,540	22,570
East Kingston	838	910	1,190	1,500	2,010	2,540	3,020	3,500	3,960	4,420	4,880
Epping	2,356	2,490	3,030	3,750	4,510	5,360	6,110	6,770	7,370	7,920	8,450
Exeter	8,892	9,900	10,720	11,570	12,460	13,350	14,050	14,590	14,780	14,300	13,150
Farmington	3,588	3,570	3,600	3,700	3,750	4,090	4,200	4,230	4,320	4,400	4,510
Fremont	993	1,170	1,500	2,000	2,500	3,550	4,740	6,230	8,060	10,000	12,080
Greenland	1,784	1,970	2,210	2,800	4,000	5,100	6,170	7,480	8,730	9,910	11,080
Hampstead	2,401	3,120	4,620	5,690	6,540	7,200	7,640	8,400	8,950	9,480	10,020
Hampton	8,011	9,010	10,250	12,650	15,170	15,510	15,800	16,060	16,420	16,650	16,770
Hampton Falls	1,254	1,350	1,500	1,670	1,850	1,870	1,890	1,920	1,950	1,960	1,970
Kensington	1,044	1,130	1,350	1,630	1,920	2,220	2,500	2,790	3,080	3,390	3,700
Kingston	2,882	3,690	4,640	5,270	5,780	6,190	6,470	6,560	6,510	6,320	5,990
Lee	1,481	1,560	1,780	2,020	2,120	2,180	2,300	2,390	2,470	2,550	2,630
Madbury	704	730	880	1,040	1,100	1,150	1,210	1,260	1,320	1,360	1,370
Middleton	430	430	450	480	490	490	500	530	530	550	580
Milton	1,859	2,160	2,450	2,780	2,900	2,990	3,160	3,230	3,310	3,390	3,480
New Castle	975	860	940	1,040	1,140	1,230	1,290	1,350	1,370	1,380	1,340
Newfields	843	780	1,000	1,100	1,200	1,350	1,480	1,680	1,880	2,110	2,340

TABLE II-2 (Cont'd)

POPULATION PROJECTIONS FOR COMMUNITIES WITHIN THE STUDY AREA

Community	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Newington	798	580	1,570	2,000	2,750	3,500	3,930	4,640	5,280	5,860	6,410
New Market	3,361	3,520	3,680	3,740	3,800	3,820	3,900	4,070	4,430	4,970	5,780
Newton	1,920	2,580	4,060	4,090	5,920	6,540	6,960	7,410	7,820	8,220	8,620
North Hampton	3,259	3,410	4,910	6,540	8,000	9,340	10,540	12,120	13,530	14,820	16,000
Northwood	1,526	1,820	1,840	1,860	1,870	1,890	1,900	1,900	1,900	1,920	1,930
Nottingham	925	1,140	1,310	1,510	1,590	1,640	1,740	1,810	1,870	1,920	1,970
Plaistow	4,712	5,330	6,550	7,340	7,960	8,430	8,750	9,070	9,350	9,620	9,920
Portsmouth	25,717	27,290	28,430	28,680	28,930	29,440	29,790	30,220	30,540	30,550	30,360
Raymond	3,003	3,960	4,230	4,300	4,420	4,470	4,580	4,670	4,720	4,790	4,850
Rochester	17,938	19,410	20,200	20,700	20,900	21,070	21,500	21,650	21,840	22,040	22,300
Rollingsford	2,273	2,010	2,100	2,240	2,300	2,320	2,400	2,490	2,560	2,630	2,680
Rye	4,083	4,190	5,230	6,570	7,980	9,330	10,530	11,520	12,660	13,670	14,590
Salem	20,142	24,630	31,000	33,250	35,500	37,750	40,000	40,680	40,800	40,680	40,430
Sandown	741	1,130	1,450	1,680	1,860	2,010	2,100	2,150	2,210	2,260	2,320
Seabrook	3,053	4,990	6,000	7,120	8,100	9,280	9,880	10,790	9,960	9,300	8,140
Somersworth	9,026	9,360	9,450	9,500	9,600	9,530	9,650	9,870	10,150	10,450	10,800
South Hampton	558	630	800	1,000	1,200	1,600	1,970	2,340	2,740	3,170	3,620
Strafford	965	1,110	1,170	1,260	1,300	1,320	1,370	1,390	1,410	1,440	1,460
Stratham	1,512	1,850	2,500	3,400	4,200	5,600	6,910	8,390	9,870	11,210	12,330
Wakefield	1,420	1,680	1,780	1,800	1,830	1,850	1,870	1,850	1,870	1,880	1,910
TOTALS	188,289	212,570	244,240	269,310	291,930	313,630	331,410	350,730	368,210	385,210	402,160

POPULATION COMPARISONS - OCP AND STATEWIDE WATER SUPPLY STUDY

COMMUNITY	1970	1980		1990		2000		2010		2020	
	Actual Data	Statewide Study	OCP*	Statewide Study	OCP*	Statewide Study	OCP*	Statewide Study	C o E** (OCP)	Statewide Study	C o E** (OCP)
Atkinson	2,291	4,600	5,670	7,500	8,910	10,500	10,580	13,000	11,970	14,500	13,250
Barrington	1,865	3,300	3,250	7,000	3,770	14,000	4,070	25,000	4,360	40,000	4,630
Brentwood	1,468	2,300	2,170	3,700	3,880	5,600	5,700	8,200	7,520	13,000	9,420
Brookfield	198	300	320	400	330	500	340	700	360	1,000	370
Candia	1,997	5,200	2,450	5,200	2,590	9,400	2,700	18,000	2,820	35,000	2,910
Chester	1,382	2,600	1,720	5,600	1,800	11,000	1,870	21,000	1,940	37,000	2,020
Danville	924	1,500	1,850	2,800	2,930	5,400	3,570	9,800	4,040	14,000	4,440
Deerfield	1,178	1,800	1,770	3,600	1,950	7,000	2,020	13,000	2,130	22,000	2,220
Dover	20,850	29,000	24,000	35,000	25,320	41,000	26,500	44,000	28,340	46,000	29,570
Durham	8,869	14,000	10,390	20,000	10,800	25,000	11,200	29,000	14,240	31,000	22,570
East Kingston	838	1,200	1,190	1,900	2,010	3,100	3,020	5,200	3,960	8,400	4,880
Epping	2,356	3,700	3,030	5,400	4,510	8,200	6,110	13,000	7,370	22,000	8,450
Exeter	8,892	8,500	10,720	9,200	12,460	10,000	14,050	10,500	14,780	11,000	13,150
Farmington	3,588	4,000	3,600	5,200	3,750	8,400	4,200	14,000	4,320	22,000	4,510
Fremont	993	1,500	1,500	2,500	2,500	4,800	4,740	10,500	8,060	22,000	12,080
Greenland	1,784	2,800	2,210	5,400	4,000	9,200	6,170	15,000	8,730	21,000	11,080
Hampstead	2,401	4,500	4,620	6,800	6,540	9,400	7,640	11,800	8,950	13,500	10,020
Hampton	8,011	8,600	10,250	10,500	15,170	12,000	15,800	14,000	16,420	15,200	16,770
Hampton Falls	1,254	1,600	1,500	2,600	1,850	4,800	1,890	8,400	1,950	11,500	1,970
Kensington	1,044	1,900	1,350	4,000	1,920	8,000	2,500	13,000	3,080	18,000	3,700
Kingston	2,882	7,000	4,640	12,000	5,780	18,000	6,470	25,000	6,510	32,000	5,990
Lee	1,481	2,200	1,780	4,000	2,120	6,000	2,300	8,000	2,470	9,800	2,630
Madbury	704	800	880	1,200	1,100	1,900	1,210	4,300	1,320	9,000	1,370
Middleton	430	300	450	500	400	700	500	1,100	530	1,700	580
Milton	1,859	2,000	2,450	2,400	2,900	2,900	3,160	3,800	3,310	5,600	3,480
New Castle	975	1,600	940	2,600	1,140	4,000	1,290	6,000	1,370	8,200	1,340
Newfields	843	800	1,000	900	1,200	1,000	1,480	1,300	1,880	1,800	2,340
New Market	3,361	3,800	3,680	4,300	3,800	5,200	3,900	6,400	4,430	8,400	5,780
Newington	798	4,200	1,570	6,800	2,750	10,000	3,930	14,500	5,280	18,500	6,410
Newton	1,920	4,500	4,060	7,500	5,920	11,200	6,960	15,000	7,820	18,500	8,620
North Hampton	3,259	8,000	4,910	13,000	8,000	17,000	10,540	18,500	13,530	19,000	16,000
Northwood	1,526	1,900	1,840	2,300	1,870	3,000	1,900	4,100	1,900	6,800	1,930
Nottingham	925	1,400	1,310	2,500	1,590	4,500	1,740	8,800	1,870	17,000	1,970
Plaistow	4,712	9,500	6,550	15,000	7,960	20,000	8,750	24,000	9,350	28,500	9,920
Portsmouth	25,727	21,000	28,430	20,500	28,930	20,000	29,790	19,500	30,540	19,000	30,360
Raymond	3,003	4,300	4,230	6,600	4,420	10,000	4,850	15,500	4,720	24,000	4,850
Rochester	17,938	23,000	20,200	29,000	20,900	37,000	21,500	50,000	21,840	68,000	22,300
Rollingsford	2,273	2,700	2,100	3,200	2,300	3,800	2,400	4,500	2,560	5,400	2,680
Rye	4,083	5,800	5,230	8,500	7,890	12,500	10,530	17,000	12,660	24,000	14,590
Salem	20,142	31,000	31,000	340,000	35,500	35,000	40,000	36,000	40,800	36,000	40,430
Sandown	741	1,200	1,450	2,200	1,860	3,900	2,100	8,600	2,210	13,500	2,320
Seabrook	3,053	4,800	6,000	6,600	8,100	8,000	9,880	10,500	9,960	14,500	8,140
Somersworth	9,026	11,000	9,450	12,500	9,600	14,000	9,650	16,000	10,150	19,000	10,800
South Hampton	558	800	800	1,200	1,200	2,000	1,970	4,000	2,740	8,200	3,620
Strafford	965	1,300	1,170	2,000	1,300	3,000	1,370	5,000	1,410	8,600	1,460
Stratham	1,512	2,500	2,500	4,200	4,200	7,000	6,910	11,500	9,870	18,000	12,330
Wakefield	1,420	1,500	1,500	1,800	1,800	2,300	1,870	3,000	1,870	4,000	1,910
TOTALS	188,289	261,880	244,240	351,600	291,930	472,200	331,410	639,000	368,210	865,100	402,160

* Office of Comprehensive Planning.
** Corps of Engineers' Estimates Based on OCP Data.

As shown in the table, there are not only significant community differences, but also significant regional differences. The Statewide Study for example as shown on Plate 2, indicates a population growth of 603,000 from 261,800 in 1980 to 865,100 in 2020. The estimates used in this report indicate a total population growth of 157,900 from 244,240 in 1980 to 402,160 in 2020. The projected 2020 population difference between these two predictions, (about 463,000 people), is larger than the estimated 2020 population used in this report. This difference in population estimates, of course, makes a considerable difference in the projected water demands of the region prepared by this study and the earlier statewide effort. In addition, other factors, discussed later, cause even further divergence of demand estimates developed in the two reports.

2. Population Locations

Pinpointing of future population locations is the prerogative of the local authorities, i.e., local planning and zoning boards. The Regional Planning Agencies within the study area have developed future land use plans, with varying degrees of detail. Although these land use plans were consulted during this study the inconsistency in detail precluded their direct use. It was decided therefore that historical trends in populations served by a public water utility would be adequate for the purposes of this report in determining the serviced population.

3. Gallon Per Capita Per Day Rates

a. Communities presently served

Domestic water usage is defined, for the purposes of this report, as all water publically supplied less identified industrial usage. Thus, domestic demands include municipal, commercial and light industrial as well as home water usage. Domestic gallon per capita per day (gpcd) rates for the various communities were obtained by dividing the average daily domestic demands by the estimated serviced population. Reliable data of this type is extremely difficult to obtain for a large region such as this, however, the New Hampshire Water Supply and Pollution Control Commission did obtain and provide enough information to make estimates of the gpcd rates. These rates are important because they provide the means to estimate each community's future domestic demand and allow a pooled estimate of future domestic demands to be calculated for communities presently without a public water supply system.

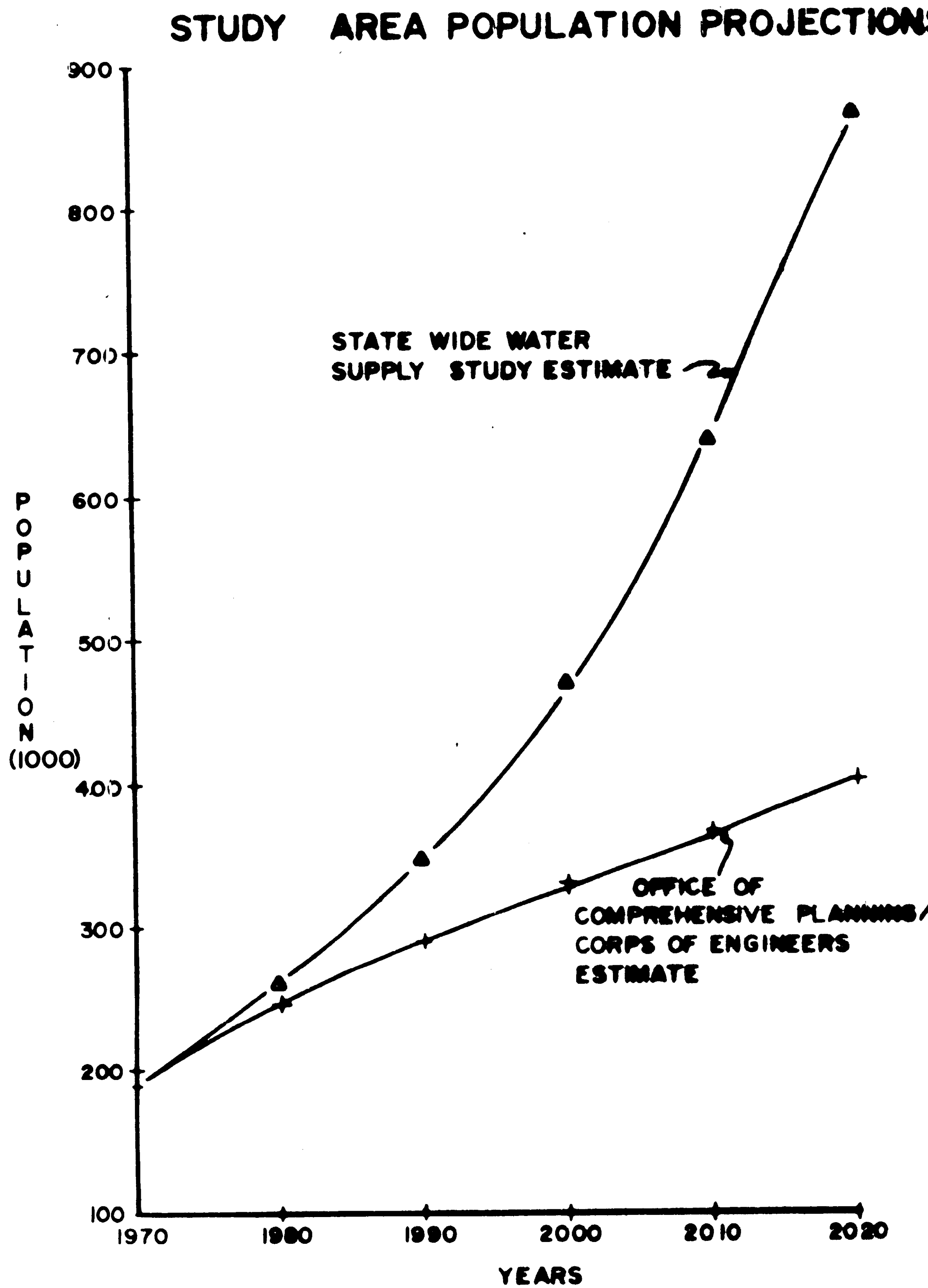
STUDY AREA POPULATION PROJECTIONS
900
800
700
600
500
400
300
200
100
POPULATION (1000)
STATE WIDE WATER SUPPLY STUDY ESTIMATE
OFFICE OF COMPREHENSIVE PLANNING/ CORPS OF ENGINEERS ESTIMATE
1970
1980
1990
2000
2010
2020
YEARS

PLATE 2

Historically, the gpcd rates have tended to increase with time, and this increase is generally attributed to more widespread use of labor saving, but water using, devices such as clothes and dish washers. However, the burgeoning public awareness concerning resource conservation may dampen the rate of increase. As a result, one of the demand estimates discussed later includes the impact of water saving appliances on future domestic demands.

At present, 22 communities are served by public systems from seventeen separate suppliers. Twelve of these seventeen provided enough information to allow trending of their individual gpcd rates and data on ten of these is shown on Table II-4. (Hampton and Seabrook were not included in Table II-4 due to the large variation in summer populations which these communities experience.) For the other five communities the gpcd rates were calculated by the equation developed for use with the new system communities except that if the calculated 1980 value was less than the value obtained in the New Hampshire 1974 Water Supply report, the 1974 value was used for 1980. Table II-5 lists all of the communities currently served by a public system and their future domestic gpcd rate based on a continuation of past trends.

Population served estimates for the twelve presently supplied communities which furnished sufficient information was based upon that system's historical patterns. The remaining five municipalities, which are presently served but for which limited data was available, had their future serviced population estimated in a manner similar to that for new supply systems. Table II-6 lists the communities presently served by public systems and their estimated future serviced population.

b. Communities not presently served.

As previously discussed, 25 of the Study Area's 47 communities are not presently served by a public water supply system. Population growth can be expected to force some of these communities to install a public water supply system within this study's time frame. Because of the uniqueness of each community, pinpointing the exact time or set of conditions when such a system would be installed requires detailed study beyond the scope of this report. However, in order for this report to evaluate the impact of these communities on the resource base, an estimate was required of these communities' future needs.

It therefore becomes necessary to establish a criterion for a community's initiation of a public water supply system. The criterion selected for this report is density, that is, the average number of people per acre living in a community. In order to determine a

TABLE II-4

PUBLIC WATER SUPPLIES - POPULATION SERVED AND DOMESTIC GPCD RATES
(Available Data)

COMMUNITY		'59	'60	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75
Dover	Pop	-	-	-	-	-	20,510	20,680	-	21,290	21,730	22,160	22,600	23,040
	GPCD	-	-	-	-	-	85	83	-	70	76	90	79	101
Durham	Pop	-	-	5,558	5,844	6,377	6,787	6,842	8,101	8,268	8,657	8,666	9,068	9,473
	GPCD	-	-	93	93	107	89	93	87	91	93	91	82	78
Exeter	Pop	-	-	8,000	8,178	8,354	8,535	8,714	8,892	9,094	9,295	9,497	9,698	9,900
	GPCD	-	-	77	78	72	75	84	80	84	66	83	76	78
Farmington	Pop	-	-	-	-	-	-	2,250	-	-	-	-	2,250	-
	GPCD	-	-	-	-	-	-	68	-	-	-	-	109	-
Newmarket	Pop	2,700	-	-	-	-	-	3,280	-	-	-	-	3,280	-
	GPCD	56	-	-	-	-	-	84	-	-	-	-	84	-
Portsmouth	Pop	-	34,000	35,596	-	-	-	-	-	-	37,865	-	39,560	-
	GPCD	-	88	62	-	-	-	-	-	-	81	-	80	-
Rochester	Pop	-	-	-	-	-	-	-	16,320	16,770	17,230	17,690	18,200	18,440
	GPCD	-	-	-	-	-	-	-	87	89	78	94	98	103
Salem	Pop	-	-	-	-	-	16,433	16,606	17,309	18,346	20,269	21,690	22,540	23,400
	GPCD	-	-	-	-	-	72	80	82	85	67	65	67	66
Salmon Falls (Rollinsford)	Pop	-	-	-	-	-	-	-	-	-	-	1,880	-	1,880
	GPCD	-	-	-	-	-	-	-	-	-	-	42	-	44
Somersworth	Pop	-	-	-	-	-	-	8,000	-	-	-	-	8,500	-
	GPCD	-	-	-	-	-	-	72	-	-	-	-	110	-
Average	Pop	2,700	34,000	16,368	7,011	7,367	13,066	9,842	12,656	14,754	19,174	13,597	15,077	14,356
Average	GPCD	56	88	77	86	90	80	81	84	84	77	78	87	78

TABLE II-5

DOMESTIC GPCD RATES FOR COMMUNITIES
WITH PUBLIC WATER SUPPLIES (Based on Past Trends)

Community	1970	1980	1990	2000	2010	2020
Dover	70	107	122	132	139	145
Durham	87	96	103	107	111	114
Epping	78	78	87	105	121	135
Exeter	80	80	81	85	89	100
Farmington	68	100	108	114	119	123
Greenland	82	94	99	103	106	108
Hampton	66	66	71	74	77	80
Milton	85	85	87	110	132	154
New Castle	82	94	99	103	106	108
Newfields	77	77	88	112	135	156
New Market	84	95	101	106	110	113
Newington	82	94	99	103	106	108
North Hampton	66	66	71	74	77	80
Portsmouth	82	94	99	103	106	108
Raymond	79	79	87	108	128	149
Rochester	87	111	123	135	147	159
Rollinsford	59	65	87	109	130	152
Rye	82	94	99	103	106	108
Salem	82	97	104	108	112	117
Seabrook	58	69	82	96	98	117
Somersworth	85	128	150	164	176	185
Wakefield	129	165	181	193	204	213

TABLE II-6

ESTIMATED SERVED POPULATIONS FOR COMMUNITIES WITH PUBLIC WATER SUPPLIES

Community	1970	1980	1990	2000	2010	2020
Dover	20,850	24,000	25,320	26,500	28,340	29,570
Durham	8,100	9,905	10,365	10,825	13,455	19,535
Epping	1,040	1,870	2,960	4,210	5,240	6,140
Exeter	8,890	10,720	12,460	14,050	14,780	13,150
Farmington	2,250	2,300	2,440	2,770	2,850	3,020
Greenland	1,470	2,210	4,000	6,170	8,730	11,080
Hampton	13,480	20,120	30,840	31,520	32,470	32,520
Milton	940	1,410	1,710	1,890	1,990	2,110
New Castle	880	940	1,140	1,290	1,370	1,340
Newfields	800	640	790	1,000	1,320	1,710
New Market	3,280	3,680	3,800	3,900	4,430	5,780
Newington	50	160	360	630	950	1,350
North Hampton	1,840	7,890	13,650	18,460	24,180	28,810
Portsmouth	31,840	35,330	35,830	36,690	37,440	37,260
Raymond	2,200	2,710	2,850	2,970	3,080	3,170
Rochester	16,320	20,200	20,900	21,500	21,840	22,300
Rollinsford	1,270	2,100	2,300	2,400	2,560	2,680
Rye	4,080	5,230	7,980	10,530	12,660	14,590
Salem	17,310	31,000	35,500	40,000	40,800	40,400
Seabrook	3,650	7,170	9,680	11,010	11,900	9,730
Somersworth	8,100	9,450	9,600	9,650	10,150	10,800
Wakefield	700	980	1,020	1,050	1,050	1,090
TOTAL	149,340	200,015	235,765	259,015	281,585	298,135

density value for the study area, three earlier reports concerned with water supply in New Hampshire communities were analyzed. The first of these-the Statewide Water Supply Study[1]-appears to use an average density of 0.23 persons per gross land area of a community. The second report-the Water Supply and Sewage Study of Rockingham and Strafford Counties[2]-appears to use an average density of about 0.38 while the third report-Water Resources Management of the Nashua Regional Planning Commission[3]-used 0.5 as the appropriate density figure. For the purposes of this report, these values were averaged, and 0.35 persons per acre selected as the appropriate density figure. At first glance, this figure may initially appear low, however, it should be remembered that roads and highways, municipal buildings, swamps and wetlands are included in the total community's area. Also, no attempt was made to classify areas within a community as easily buildable, or unsuitable for building.

Communities within the study area which have a public water supply system provided the basis for predicting the number of residents to be served by these newly formed public water supply systems. All data for communities with population densities less than unity were first analyzed to determine estimates of their future served populations. These percent population served numbers were then regressed against the appropriate density numbers to generate a predictive curve. The general form of the equation was:

$Y=b_0x^{b_1}$, where

Y=percent of the population served

X=density

B_0 and b_1 are constants determined by regression analysis. This particular mathematical model was selected because it will "bend" the curve more at higher density numbers reflecting conditions often found in mature communities.

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1 Ibid

2 <u>Comprehensive Report On Water Supply and Sewerage For Rockingham and Strafford Counties</u>; prepared for the New Hampshire Water Supply and Pollution Control Commission by Alonzo B. Reed, Inc.; August, 1968.

3 <u>Comprehensive Regional Water Quality Management Plan</u>; prepared for the Nashua Regional Planning Commission by Howard, Needles, Tammen and Bergendoff; December, 1973.

Plate 3 illustrates the curve resulting from this analysis, indicating that at approximately 3.75 people per acre, 100 percent of the community's population is served.

Thus, density relationships based upon the State's and the region's experience determined which of the 25 communities not now served by a public water supply system would be, and the number of community residents served by that system.

Table II-7 lists communities anticipated to initiate public water supply systems within this study's time frame. The first appearance of a served population and percent of total community population served figure, indicates the target year by which it is expected the system will be in operation. Plate 4 presents a graphic illustration of this phasing. Thus, Kensington is not expected to have a public water supply system until the 2001 to 2010 decade, while Plaistow is expected to have a system in operation by the year 1980.

For those communities which do not presently have a public water supply system, three prediction techniques were used to estimate future domestic gpcd rates. All three techniques were based on the region's past experience with domestic demands. Table II-5 lists the data used in this report for estimating future domestic gpcd rates.

The large variances among the communities, and in some instances among the rates for the same community, led to the use of pooled gpcd and served population estimates as the projection base. These figures are also listed on Table II-4. The first estimation technique employed for communities which do not presently have public water supply systems was based on trending the served population and gpcd estimates together, because of the shape of the curve of served population or gpcd rates against time. This type of analysis would yield a different gpcd rate for each community based upon the estimated served population. The resulting equation which this analysis yielded was:

$y = 60.64 + 2.54(t) + 0.000927\ (P) - 0.000142\ (t)\ (P)$ where:

y = the estimated domestic gpcd rate

t - time, in years (starting year = 1)

P - served population

60.64, 2.54, 0.000927 and -0.000142 are constants determined by regression analysis.

The second technique employed was a straight line relationship between years and the observed gpcd rates. The equation generated by this technique was:

PERCENT POPULATION SERVED - COMMUNITY DENSITY

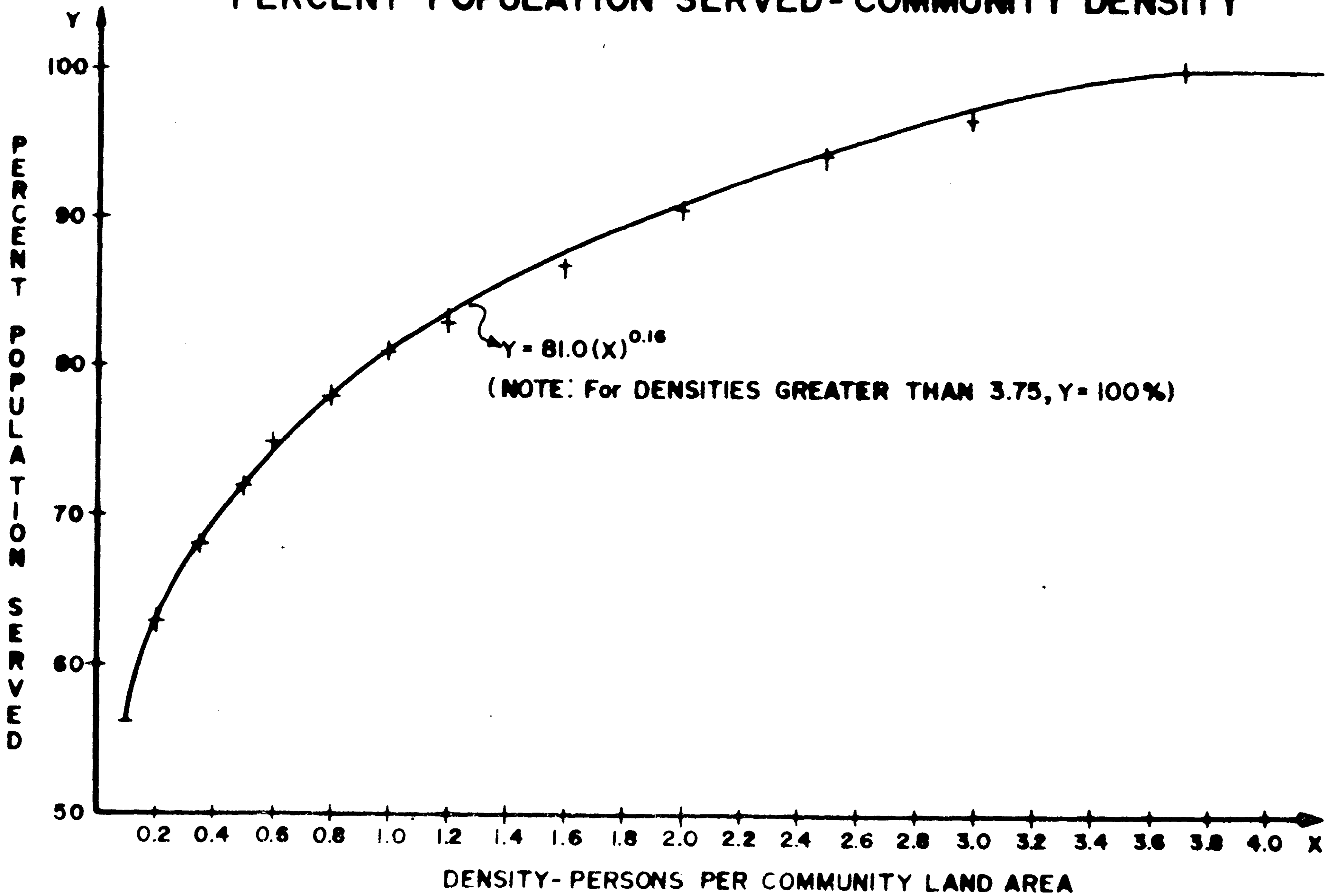


PLATE 3

TABLE II-7

SERVED POPULATIONS AND PERCENT OF COMMUNITY'S POPULATION SERVED FOR COMMUNITIES WITH NEW SYSTEMS

Community	1980		1990		2000		2010		2020	
	Served Population	%	Served Population	%	Served Population	%	Served Population	%	Served Population	%
Atkinson	4,440	78	7,500	84	9,150	86	10,560	88	11,880	90
Brentwood			2,670	69	4,170	73	5,760	76	7,470	79
Danville			2,050	70	2,570	72	2,970	74	3,310	75
East Kingston					2,180	72	2,980	75	3,800	78
Fremont					3,360	71	6,210	77	9,940	82
Hampstead	3,380	73	5,060	77	6,060	79	7,280	81	8,300	83
Kensington							2,160	70	2,680	72
Kingston	3,210	69	4,150	72	4,730	73	4,760	73	4,320	72
Newton	3,070	76	4,750	80	5,730	82	6,560	84	7,350	85
Plaistow	5,290	81	6,630	83	7,400	84	7,990	85	8,550	86
South Hampton					1,380	70	2,020	74	2,790	77
Stratham			2,980	71	5,300	77	8,020	81	10,380	84
TOTALS	19,390	-	35,790	-	52,030	-	67,270	-	80,770	-

NOTE: Served Population Numbers are Rounded to the Nearest Ten; Percentages are Rounded to Nearest Whole Number.

SOUTHEAST NEW HAMPSHIRE WATER SUPPLY STUDY

PHASING OF NEW SYSTEMS

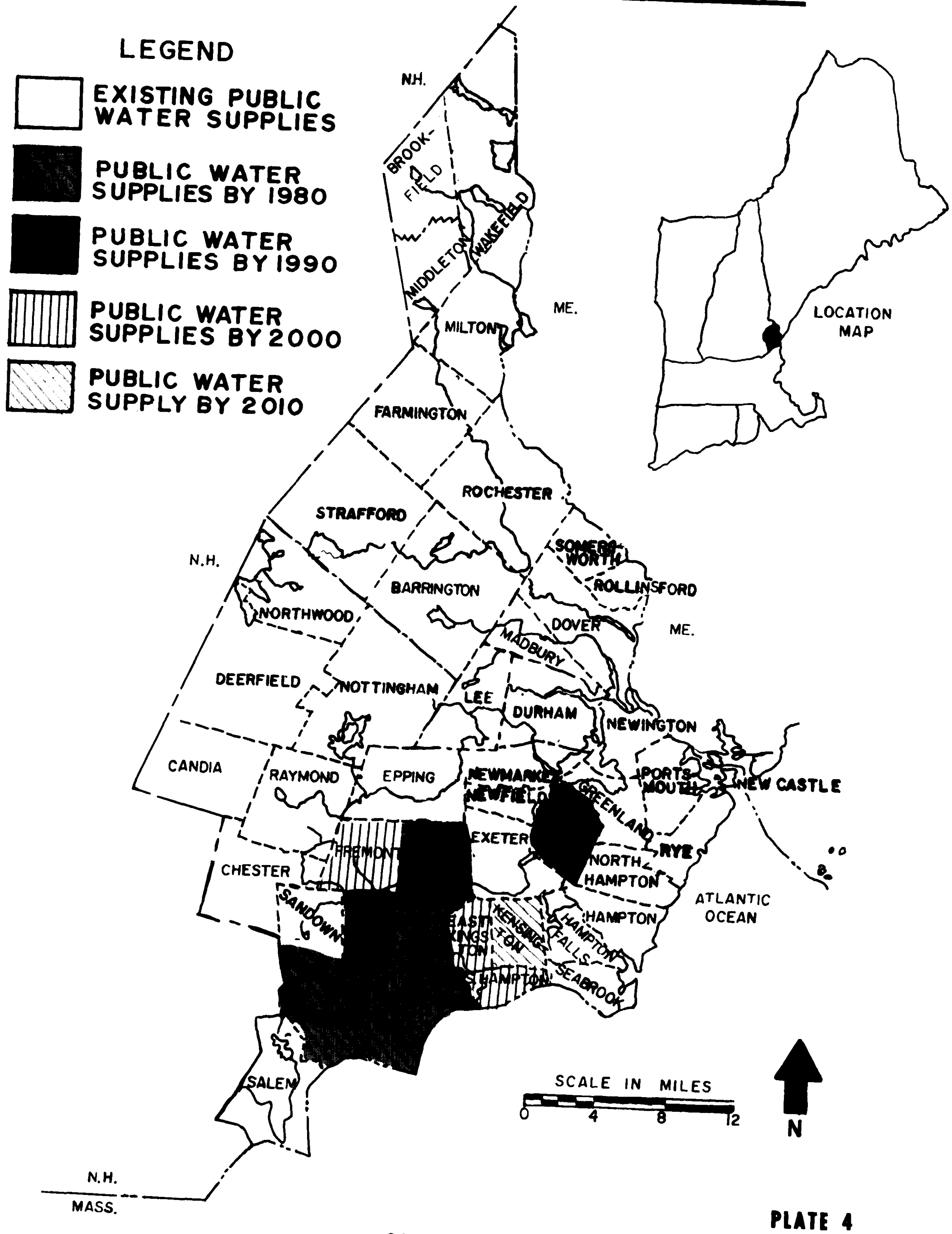


PLATE 4

$Y = 74.0 + 0.65\ X$
where:

y = the estimated domestic gpcd rate

x = time, in years (starting year = 1)

74.0 and 0.65 are constants determined by regression analysis.

The third technique, based on reduction of demand through the widespread usage of conservation measures, used a percentage reduction of the previously estimated straight line relationship demand rates. This percentage reduction can be calculated by:

$S = Pd/(100+P)$
where:

S = percent reduction of domestic demand

P = percent population increase from the base year

d = 16% maximum percent reduction of domestic demand attributable to the installation of water saving toilets and shower heads.

Due to a lack of data, no estimation of replacement housing was available, therefore, the above equation assumes that only new housing will have the water saving devices installed. Should an appreciable amount of replacement housing, or retrofit devices be employed, the percentage reductions calculated by the above equation would be lower than the actual reduction achieved. The 16% reduction factor was estimated for household water usage only, however, not for domestic demand as defined for this report, therefore the percentage reductions calculated by the above equation may tend to be higher than actually attained. Although these two factors will distort the percentage reduction estimates, the distortions will be in opposite directions.

The following assumptions are implicit in the use of this method:

1. Institutional changes will be made, so that all new dwelling units must be supplied with water-saving toilets (3.5 gallon per flush models) and shower heads (3 gallons per minute).

2. The number of persons per dwelling unit in 1970 will remain constant with a value of 3.1 (In fact, the study area had an overall decrease from 3.2 persons per dwelling unit in 1950 to 3.1 in 1970; Rockingham County, however, remained constant at 3.2).

3. Each new dwelling will be equipped with 2 toilets and 1 shower head.

4. Estimated Domestic Demands

Future domestic water demands were estimated by multiplying the estimated served population by the appropriate gpcd rate. Table II-8 lists the domestic demands anticipated if the conservation measures previously described are implemented. As shown in the table, this estimate basis gives the lowest domestic demands for the region, increasing from approximately 18.6 million gallons per day (mgd) in 1980 to 39.5 mgd in 2020.

Table II-9 lists the domestic demands estimated by a straight line relationship developed from the averaged gallon per day rates of the existing systems. This method gives the middle value of the three forecasting techniques used with demands increasing from 19.3 mgd in 1980 to 43.2 mgd by 2020. This method however, for some of the existing systems does not follow the historic trend of that system.

Table II-10 lists the domestic demands which were estimated by analyzing the trend of each individual system. For the 12 communities which are anticipated to establish public water supply systems, the demands were estimated by the multiple linear regression analysis technique which considered population served as well as time. Although this estimation yields the highest domestic demand values - from 20.0 mgd in 1980 increasing to 44.9 mgd in 2020 - it is considered to yield values which most closely continue the past trends of existing systems, with one notable exception. Salem is nearing its system safe yield with its average day demands, and per capita usage has declined from 85 in 1971 to 66 in 1975. Prior to the decline, the rate had been increasing, and it has been assumed that this decline is attributable to the daily demands nearing the systems' safe yield. The increasing rate was therefore used as the indicator of what would happen if there were an adequate supply. Plate 5 illustrates the difference in the total estimated municipally supplied regional water demands which these three domestic demand techniques forecast.

B. Industrial Demands

1. Location of Industries

Although industries are located in many of the Study Area's communities, significant concentrations are located in the following communities:

TABLE II-8

FUTURE SUPPLIED DOMESTIC DEMANDS - BY TOWN, BY YEAR
(Conservation Measures Technique)

Town	1980	1990	2000	2010	2020
Atkinson	376,100	668,000	860,200	1,046,200	1,238,700
Brentwood	0.0	238,100	392,400	570,400	779,500
Danville	0.0	182,400	242,000	294,400	345,700
Dover	2,033,600	2,256,000	2,491,400	2,808,300	3,083,700
Durham	839,300	923,500	1,017,700	1,333,300	2,037,200
East Kingston	0.0	0.0	204,900	295,800	396,600
Epping	158,300	264,100	396,200	519,100	640,100
Exeter	908,400	1,110,200	1,320,900	1,464,600	1,371,400
Farmington	194,900	217,400	260,400	282,400	314,900
Fremont	0.0	0.0	315,700	615,800	1,036,100
Greenland	187,300	356,400	580,100	865,100	1,155,500
Hampstead	286,700	451,200	570,100	721,900	866,000
Hampton	1,704,900	2,747,800	2,963,300	3,217,600	3,391,400
Kensington	0.0	0.0	0.0	214,300	279,000
Kingston	272,400	369,500	444,400	417,800	450,800
Milton	119,100	152,200	177,400	197,400	220,100
New Castle	79,600	101,600	121,300	135,800	139,700
Newfields	53,900	70,100	94,300	131,100	177,900
New Market	311,800	338,600	366,700	439,000	602,800
Newington	13,600	32,100	59,200	94,100	140,800
Newton	260,100	423,500	539,100	650,500	766,400
North Hampton	668,600	1,216,200	1,735,500	2,396,100	3,004,500
Plaistow	447,900	590,500	695,300	791,500	892,100
Portsmouth	2,993,700	3,192,500	3,449,400	3,710,100	3,885,700
Raymond	229,500	254,000	279,200	304,800	331,000
Rochester	1,711,600	1,862,200	2,021,300	2,164,200	2,325,600
Rollinsford	177,900	204,900	225,600	253,700	279,500
Rye	443,200	711,000	990,000	1,254,500	1,521,500
Salem	2,626,800	3,163,100	3,760,600	4,043,100	4,216,300
Seabrook	607,500	862,500	1,110,300	1,179,200	1,014,700
Somersworth	800,700	855,400	907,200	1,005,800	1,126,300
South Hampton	0.0	0.0	129,600	200,200	291,100
Stratham	0.0	265,200	498,500	794,400	1,082,200
Wakefield	83,000	90,900	98,700	104,000	113,700
TOTALS	18,590,400	24,171,100	29,318,900	34,516,500	39,518,500

TABLE II-9

FUTURE SUPPLIED DOMESTIC DEMANDS, BY TOWN, BY YEAR
(STRAIGHT LINE RELATIONSHIP)

Town	1980	1990	2000	2010	2020
Atkinson	390,570	708,370	923,960	1,134,730	1,353,760
Brentwood	0.0	252,480	421,520	618,650	851,870
Danville	0.0	193,410	259,920	319,310	377,780
Dover	2,111,760	2,392,380	2,676,020	3,045,920	3,370,200
Durham	871,540	979,350	1,093,130	1,446,110	2,226,470
East Kingston	0.0	0.0	220,130	320,790	433,430
Epping	164,430	280,030	425,590	562,980	699,590
Exeter	943,250	1,177,290	1,418,790	1,588,520	1,498,750
Farmington	202,380	230,550	279,720	306,310	344,200
Freemont	0.0	0.0	339,080	667,940	1,132,400
Greenland	194,460	377,940	823,060	938,280	1,262,830
Hampstead	297,750	478,430	612,330	783,000	946,500
Hampton	1,770,360	2,913,940	3,182,940	3,489,800	3,706,420
Kensington	0.0	0.0	0.0	232,480	304,960
Kingston	282,850	391,860	477,310	511,660	492,660
Milton	123,630	161,430	190,590	214,060	240,570
New Castle	82,710	107,710	130,270	147,240	152,720
Newfields	56,000	74,290	101,260	142,230	194,400
Newmarket	323,800	359,050	393,830	476,130	658,770
Newington	14,080	34,010	63,620	102,100	153,860
Newton	270,080	449,130	579,100	705,510	837,610
North Hampton	694,240	1,289,730	1,864,120	2,598,810	3,283,580
Plaistow	465,140	626,190	746,850	858,440	974,990
Portsmouth	3,108,680	3,385,430	3,705,020	4,023,960	4,246,660
Raymond	238,340	269,310	299,940	330,580	361,780
Rochester	1,777,400	1,974,750	2,171,110	2,347,310	2,541,610
Rollinsford	184,780	217,320	242,360	275,140	305,450
Rye	460,190	754,000	1,063,340	1,360,670	1,662,870
Salem	2,727,690	3,354,250	4,039,270	4,385,090	4,607,950
Seabrook	630,890	914,620	1,192,590	1,278,980	1,108,960
Somersworth	831,500	907,060	974,470	1,090,900	1,230,910
South Hampton	0.0	0.0	139,180	217,180	318,100
Stratham	0.0	281,240	535,430	861,640	1,182,730
Wakefield	86,230	96,380	106,030	112,850	124,230
TOTALS	19,304,720	25,631,930	31,491,870	37,495,280	43,189,550

TABLE II-10

FUTURE SUPPLIED DOMESTIC DEMANDS, BY TOWN, BY YEAR
(Multiple Linear Regression Analysis)

Town	1980	1990	2000	2010	2020
Atkinson	295,920	628,150	870,240	1,083,180	1,265,150
Brentwood	0.0	232,060	439,650	686,510	957,100
Danville	0.0	178,580	279,560	383,070	491,890
Dover	2,568,000	3,089,040	3,498,000	3,939,260	4,287,650
Durham	950,880	1,067,600	1,158,280	1,493,510	2,226,990
East Kingston	0.0	0.0	238,520	384,700	555,260
Epping	145,860	256,840	443,550	634,160	826,130
Exeter	857,600	1,009,260	1,194,250	1,315,420	1,315,000
Farmington	230,000	263,520	315,780	339,150	371,460
Freemont	0.0	0.0	359,300	731,310	1,152,670
Greenland	207,740	396,000	635,510	925,380	1,196,640
Hampstead	222,790	432,000	615,150	830,210	1,029,690
Hampton	1,327,920	2,189,640	2,322,480	2,500,190	2,601,600
Kensington	0.0	0.0	0.0	284,970	405,430
Kingston	211,220	356,290	492,490	584,240	620,150
Milton	119,850	149,420	207,650	263,580	325,670
New Castle	88,360	112,860	132,870	145,220	144,720
Newfields	49,280	69,220	112,140	178,200	266,550
New Market	349,600	383,800	413,400	487,300	653,140
Newington	15,040	35,640	64,890	100,700	145,800
Newton	201,330	406,530	585,640	764,480	945,570
North Hampton	520,740	969,150	1,366,040	1,861,860	2,304,800
Plaistow	355,930	558,930	730,060	890,740	1,050,230
Portsmouth	3,321,020	3,547,170	3,779,070	3,968,640	4,024,080
Raymond	214,090	247,210	320,190	395,470	473,240
Rochester	2,242,200	2,570,700	2,902,500	3,210,480	3,545,700
Rollinsford	136,140	200,280	261,520	333,730	406,030
Rye	491,620	790,020	1,084,590	1,341,960	1,575,720
Salem	3,007,000	3,692,000	4,320,000	4,569,600	4,730,310
Seabrook	493,370	797,640	1,058,750	1,165,420	1,138,590
Somersworth	1,209,600	1,440,000	1,582,600	1,786,400	1,998,000
South Hampton	0.0	0.0	153,080	267,210	421,330
Stratham	0.0	257,920	546,180	893,230	1,181,480
Wakefield	161,700	184,620	202,650	214,200	232,170
TOTALS	19,994,800	26,512,150	32,696,580	38,953,640	44,865,940

Dover	Newmarket
Epping	Plaistow
Farmington	Seabrook
Newfields	Somersworth
Newington	

It is interesting to note that, with the single exception of Plaistow, all other communities with significant industrial employment are served by a public water supply system.

2. Industrial Demand Estimation Techniques

Industrial water demand data was gathered for this study by the New Hampshire Water Supply and Pollution Control Commission from public water supplies which serve the industries. Industrial demands were aggregated by community according to a two digit SIC Code. The SIC (Standard Industrial Classification) Codes were established by the Federal Government to permit categorization and identification of industry. The codes are set up on a 2, 3, and 4 digit flexible system, with identification becoming more specific as the number of digits increase. For example, an industry with the Code 2822 would be identified in the following manner: the major industrial code - 28 - indicates chemicals and allied products; the industry group - 282 - further refines it as a manufacturer of either fibers, plastics, or rubber; the specific code - 2822 - identifies the plant as a manufacturer of Synthetic Rubber.

Seven two digit SIC Code industries have been identified as major water users within the study area. These are listed below in Table II-11.

TABLE II-11

SIC Code	1970 Municipally Supplied Regional Industrial Demand (MGD)	DEFINITION
20	0.133	Food and Kindred Products
28	0.057	Chemical and Allied Products
33	0.249	Primary Metal Industries
34	0.253	Fabricated Metal Products (Except Machinery & Transportation Equipment)
35	0.031	Machinery (Except Electrical)
36	0.561	Electrical and Electronic Machinery, Equipment & Supplies
39	0.961	Miscellaneous Manufacturing Industries
TOTAL	2.245	

The methodology used to estimate the region's future industrial water demand is as follows:

1. Determine, and aggregate by SIC Code, the major water using industries by community, and their water demand for a base year (1970).

2. Determine, for each of the 7 identified water using industries, the ratio of future water demand to the base year. This is accomplished by the formula: F = (ExO)/(RxT), where:

F = ratio of water usage, per SIC Code, between the projected year and the base year.

ExO = Employee Output factors, derived from the OBERS Series E Projections per SIC Code per future year.

RxT = Recirculation & Technology factors derived from the "Water Demand Study Eastern Massachusetts Region" prepared for the Northeastern United States Water Supply Study.

Table II-12 lists the F, ExO and RxT factors per SIC Code per future target year which were used in estimating future industrial water demands.

3. Industrial Demands

As previously indicated, the future industrial demands were estimated by establishing ratios of water usage in the target years to a base year for each of seven major two-digit SIC Codes. The industrial usage was estimated only for those communities with existing public systems having significant industrial demands. For the purpose of this study, significant was defined as any industry with an average daily demand greater than 5 percent of the total water supplied, or 25,000 gallons per day, whichever was lower. Essentially, this type of analysis continues past trends only. Implicitly assumed is that large water users who are self-supplied (for example, the Public Service Company, which uses an estimated 527 mgd for cooling water at its three power plants) will continue to supply themselves for whatever their future needs are; and, that industry will tend to locate and/or expand where it is presently located.

The impact of a major industry, such as an oil refinery, on the resources of the study area, although not planned for in this report, must be mentioned. Such an industry would, of course, impact on all resources of the region. Although the primary interest of a water

TABLE II-12

"F" FACTOR DETERMINATION BY SIC CODE, BY TARGET YEAR

$F = (ExO)/(RxT)$

SIC Code	1980				1990				2000				2010				2020			
	ExO	R	T	F	ExO	R	T	F	ExO	R	T	F	ExO	R	T	F	ExO	R	T	F
20	1.48	1.0	1.23	1.2	1.9	1.0	1.4	1.36	2.44	1.03	1.49	1.59	3.15	1.07	1.61	1.83	3.73	1.1	1.8	1.88
28	2.09	1.1	1.09	1.74	3.34	1.2	1.2	2.32	5.14	1.28	1.3	3.09	7.7	1.35	1.35	4.22	10.27	1.4	1.4	5.24
33	1.18	1.1	1.14	0.94	1.3	1.2	1.3	0.83	1.5	1.28	1.4	0.84	1.8	1.35	1.5	0.89	1.97	1.4	1.6	0.88
34	1.88	1.12	1.0	1.68	2.69	1.2	1.0	2.24	3.79	1.26	1.0	3.01	5.15	1.29	1.0	3.99	6.68	1.3	1.0	5.14
35	1.14	1.2	1.06	0.9	1.3	1.3	1.1	0.91	1.57	1.4	1.16	0.97	1.71	1.46	1.21	0.97	2.24	1.5	1.3	1.15
36	1.78	1.42	1.27	0.99	2.49	1.8	1.5	0.92	3.54	2.0	1.65	1.07	4.95	2.25	1.8	1.22	6.41	2.5	2.0	1.28
39	1.41	1.0	1.14	1.24	1.83	1.0	1.3	1.41	2.43	1.03	1.4	1.69	3.25	1.07	1.5	2.02	4.01	1.1	1.6	2.28

Notes: 1970 = 1 for all SIC Codes, all Factors.
ExO Factors from OBERS '72 Series "E" Projections for State of New Hampshire.
RxT Factors from "Water Demand Study - Eastern Massachusetts Region" prepared for New England Division, Corps of Engineers, dated November 1974.

resources report would be the water required by the industry itself, the secondary effects caused by the location of the industry must also be recognized. These secondary effects could include such things as an accelerated growth in neighboring communities, changing land use patterns and resource consumption.

The Governor of New Hampshire has published an information pamphlet describing the ten sites in six communities which have been proposed as possible oil refinery locations. Four of the six communities, containing eight of the ten sites are located within this report's study area. Four sites, ranging in size from 832 acres to 2,432 acres are located in Raymond. Each of these sites, however, is quoted in the Information Pamphlet as having insufficient water for processing (estimated by New Hampshire Planning officials to be about 10 mgd) as the single largest disadvantage. The review of groundwater resources performed for this study does not indicate the existence of sufficient groundwater aquifers for this purpose. (The groundwater resources of the region are discussed in the next section of the report.) Two sites in Newmarket contain 968 acres and 1,216 acres respectively. Again, the major disadvantage of these sites is the reported apparent lack of process water. The groundwater review indicates that an aquifer of approximately 1.2 mgd is located in Newmarket, however, one half of this has already been developed and it has been assumed that the community would develop the remaining amount to meet its future needs.

A 2,115 acre site in the southern portion of Rochester has been given consideration, as has a 1,344 acre site in Farmington and Rochester along the Cocheco River. The Farmington/Rochester site appears to be atop a portion of an aquifer which may have a total safe yield in excess of 7 mgd. If all, or most, of this aquifer was developed for an oil refinery, the two communities would be required to meet their future demands from another source. Also, full development of this aquifer may infringe on the low flows of the Cocheco River. These two sites are also in close proximity to the Isinglass River Reservoir which was previously proposed for required water supply in a report titled "Report on Metropolitan Water Supply for Seacoast Area".

Although the 10 mgd said to be required by an oil refinery does not compare in magnitude with a 527 mgd which the Public Service Company uses, it is still a significant amount of the region's fresh water budget. Based on New Hampshire's information pamphlet and work conducted as a part of this report, the potential locations selected within this study area do not appear capable of supporting a refinery's freshwater requirements (assuming all 10 mgd must be fresh) without some storage of water in ground or surface reservoirs. In this report, a detailed analysis was not made of what type of water supply development would best serve a refinery. Such an analysis is well beyond the scope of this particular report. Any follow up, detailed studies would however, consider the possible effects of refinery water requirements on future supply development within the study area.

Table II-13 lists estimates of future industrial demands by the communities presently supplying industries by SIC Code by target year. As shown at the end of the table, the total, publicly supplied industrial water demand is estimated to almost double between 1980 and 2020; however, this 2020 demand of 4.9 mgd represents less than 10 percent of the total estimated demand for the area, which is approximately a 3 percent decrease from present industrial demands.

C. Estimated Future Demands

Table II-14 lists the communities served; the reported 1969 and 1974 demands for the existing systems; the total averaged GPCD rates for each community for each target year; the estimated populations served; the estimated industrial demands; the estimated domestic demands (based on the continuation of past trends); and, the total estimated publicly supplied water on an average daily basis. The table is separated into two parts so that the new systems and existing systems can be analyzed separately, aggregated in their own groups, or as one regional entity. As indicated on the table in the Grand Total line the 1974 publicly supplied average daily water demand of 16.92 mgd is expected to increase to 46.36 mgd in 2020, with a corresponding served population increase from 173,366 to 374,615 in the same time period. The over-all gallon per capita per day increase is of significance for comparison purposes, with an increase of 35 from 98 to 133 in the study's time frame. Plate 5 illustrates the total estimated publicly supplied regional water demands.

The earlier statewide study by comparison indicated a total usage of 167.9 mgd by the year 2020 for the communities within this study area. As discussed earlier, differences between population estimates account for some of this variance however, this alone does not account for the total water demand difference. An estimation was made, therefore, of the total average gpcd rates used. As shown on Table II-16, the Statewide Study used an 88 gpcd increase for the period 1980-2020. In this report, the increase for this 40 year period was estimated to be about 30 gpcd. In addition, the Statewide Study assumed that nearly 100 percent of the study area population would be served by the year 2020. This report, based on its assumptions, indicated some communities within the study area may not require public water supply systems by the year 2020, and those that did may not be serving all community residents by that time.

TABLE II-13

ESTIMATED MUNICIPALLY SUPPLIED FUTURE INDUSTRIAL DEMANDS
(Average MGD)

Town	SIC Code	1970	1980	1990	2000	2010	2020
Dover	35	0.024	0.022	0.022	0.024	0.024	0.028
	36	0.067	0.066	0.061	0.071	0.081	0.085
	39	0.304	0.377	0.428	0.513	0.614	0.693
Sub-Total		0.395	0.465	0.511	0.608	0.719	0.806
Exeter	39	0.040	0.050	0.056	0.068	0.081	0.091
Farmington	39	0.087	0.108	0.123	0.147	0.176	0.198
Portsmouth	20	0.039	0.047	0.053	0.062	0.072	0.074
	33	0.249	0.234	0.206	0.209	0.221	0.219
	34	0.008	0.014	0.018	0.025	0.033	0.042
	39	0.319	0.395	0.449	0.538	0.643	0.726
Sub-Total		0.615	0.689	0.727	0.834	0.969	1.061
Rochester	20	0.052	0.062	0.002	0.002	0.003	0.003
	34	0.068	0.114	0.152	0.204	0.270	0.348
	36	0.031	0.031	0.029	0.034	0.039	0.041
	39	0.194	0.240	0.273	0.327	0.391	0.442
Sub-Total		0.345	0.447	0.456	0.567	0.703	0.834
Rollinsford	39	0.002	0.002	0.002	0.002	0.003	0.003
Salem	20	0.042	0.050	0.056	0.066	0.076	0.078
	35	0.007	0.006	0.006	0.007	0.007	0.008
	39	0.015	0.018	0.020	0.024	0.029	0.033
Sub-Total		0.064	0.074	0.082	0.097	0.112	0.119
Seabrook	28	0.057	0.100	0.133	0.177	0.242	0.300
	34	0.177	0.297	0.396	0.533	0.706	0.910
Sub-Total		0.234	0.397	0.592	0.710	0.948	1.210
Somersworth	36	0.463	0.458	0.426	0.495	0.565	0.593
TOTAL		2.245	2.690	2.975	3.528	4.276	4.915

TABLE II-14

EXISTING AND ESTIMATED MUNICIPALLY SUPPLIED TOTAL WATER DEMANDS

Community	1969			1974			1980					1990					2000					2010					2020				
	Total Demand	Served Pop.	GPCD	Total Demand	Served Pop.	GPCD	Dom. Demand	Ind. Demand	Total Demand	Served Pop.	GPCD	Dom. Demand	Ind. Demand	Total Demand	Served Pop.	GPCD	Dom. Demand	Ind. Demand	Total Demand	Served Pop.	GPCD	Dom. Demand	Ind. Demand	Total Demand	Served Pop.	GPCD	Dom. Demand	Ind. Demand	Total Demand	Served Pop.	GPCD
Atkinson							0.296	0.000	0.296	4,440	67	0.628	0.000	0.628	7,500	84	0.870	0.000	0.870	9,150	95	1.083	0.000	1.083	10,560	103	1.265	0.000	1.265	11,880	106
Brentwood							0.000	0.000	0.000	0	0	0.232	0.000	0.232	2,670	87	0.440	0.000	0.440	4,170	106	0.687	0.000	0.687	5,760	119	0.957	0.000	0.957	7,470	128
Danville							0.000	0.000	0.000	0	0	0.179	0.000	0.179	2,050	87	0.280	0.000	0.280	2,570	109	0.383	0.000	0.383	2,970	129	0.492	0.000	0.492	3,310	149
East Kingston							0.000	0.000	0.000	0	0	0.000	0.000	0.000	0	0	0.239	0.000	0.239	2,180	110	0.385	0.000	0.385	2,980	129	0.555	0.000	0.555	3,800	146
Fremont							0.000	0.000	0.000	0	0	0.000	0.000	0.000	0	0	0.359	0.000	0.359	3,360	107	0.731	0.000	0.731	6,210	118	1.153	0.000	1.153	9,940	116
Hampstead	NO EXISTING PUBLIC WATER SUPPLY						0.223	0.000	0.223	3,380	66	0.432	0.000	0.432	5,060	85	0.615	0.000	0.615	6,060	101	0.830	0.000	0.830	7,280	114	1.030	0.000	1.030	8,300	124
Kensington							0.000	0.000	0.000	0	0	0.000	0.000	0.000	0	0	0.000	0.000	0.000	0	0	0.285	0.000	0.285	2,160	132	0.405	0.000	0.405	2,680	151
Kingston							0.211	0.000	0.211	3,210	66	0.356	0.000	0.356	4,150	86	0.492	0.000	0.492	4,730	104	0.584	0.000	0.584	4,760	123	0.620	0.000	0.620	4,320	144
Newton							0.201	0.000	0.201	3,070	65	0.407	0.000	0.407	4,750	86	0.586	0.000	0.586	5,730	102	0.764	0.000	0.764	6,560	116	0.946	0.000	0.946	7,350	129
Plaistow							0.356	0.000	0.356	5,290	67	0.559	0.000	0.559	6,630	84	0.730	0.000	0.730	7,400	99	0.891	0.000	0.891	7,990	112	1.050	0.000	1.050	8,550	123
South Hampton							0.000	0.000	0.000	0	0	0.000	0.000	0.000	0	0	0.153	0.000	0.153	1,380	111	0.267	0.000	0.267	2,020	132	0.421	0.000	0.421	2,790	151
Stratham							0.000	0.000	0.000	0	0	0.258	0.000	0.258	2,980	87	0.546	0.000	0.546	5,300	103	0.893	0.000	0.893	8,020	111	1.181	0.000	1.181	10,380	114
TOTALS							1.287	0.000	1.287	19,390	66	3.051	0.000	3.051	35,790	85	5.310	0.000	5.310	52,030	102	7.783	0.000	7.783	67,270	116	10.075	0.000	10.075	76,450	132
Dover	2.100	20,680	102	2.230	22,600	99	2.568	0.465	3.033	24,000	126	3.089	0.512	3.601	25,320	142	3.498	0.608	4.106	26,500	155	3.939	0.719	4.658	28,340	164	4.288	0.806	5.094	29,570	172
Durham	0.635	6,840	93	0.740	8,720	85	0.951	0.000	0.951	9,905	96	1.068	0.000	1.068	10,365	103	1.158	0.000	1.158	10,825	107	1.494	0.000	1.494	13,455	111	2.227	0.000	2.227	19,535	114
Epping	0.083	1,000	83	0.072	1,200	60	0.146	0.000	0.146	1,870	78	0.257	0.000	0.257	2,960	87	0.444	0.000	0.444	4,210	105	0.634	0.000	0.634	5,240	121	0.826	0.000	0.826	6,140	135
Exeter	0.770	8,714	88	0.870	9,698	90	0.858	0.050	0.908	10,720	85	1.009	0.056	1.065	12,460	85	1.194	0.068	1.262	14,050	90	1.315	0.081	1.396	14,780	94	1.315	0.091	1.406	13,150	107
Farmington	0.165	2,250	73	0.347	2,250	154	0.230	0.108	0.338	2,300	147	0.264	0.123	0.387	2,440	159	0.316	0.147	0.463	2,770	167	0.339	0.176	0.515	2,850	181	0.371	0.198	0.569	3,020	188
Greenland1/	w/Portsmouth						(.208)	0.000	(.208)	2,210	94	(.396)	0.000	(.396)	4,000	99	(.636)	0.000	(.636)	6,170	103	(.925)	0.000	(.925)	8,730	106	(1.197)	0.000	(1.197)	11,080	108
Hampton2/	1.254	18,880	66	1.400	25,170	56	2.000	0.000	2.000	29,610	68	3.317	0.000	3.317	46,090	72	3.863	0.000	3.863	51,580	75	4.532	0.000	4.532	58,250	78	5.080	0.000	5.080	62,930	81
Milton	0.082	900	91	0.065	1,100	59	0.120	0.000	0.908	1,410	85	0.149	0.000	0.149	1,710	87	0.208	0.000	0.208	1,890	110	0.264	0.000	0.264	1,990	133	0.326	0.000	0.326	2,110	155
New Castle1/	w/Portsmouth						(.088)	0.000	(.088)	940	94	(.113)	0.000	(.113)	1,140	99	(.133)	0.000	(.133)	1,290	103	(.145)	0.000	(.145)	1,370	106	(.145)	0.000	(.145)	1,340	108
Newfields	0.070	800	88	0.025	800	31	0.049	0.000	0.049	640	77	0.069	0.000	0.069	790	87	0.112	0.000	0.112	1,000	112	0.178	0.000	0.178	1,320	135	0.267	0.000	0.267	1,710	156
Newington1/	w/Portsmouth						(.015)	0.000	(.015)	160	94	(.036)	0.000	(.036)	360	99	(.065)	0.000	(.065)	630	103	(.101)	0.000	(.101)	950	106	(.146)	0.000	(.146)	1,350	108
Newmarket	0.275	3,280	84	0.275	3,280	84	0.350	0.000	0.350	3,680	95	0.384	0.000	0.384	3,800	101	0.413	0.000	0.413	3,900	106	0.487	0.000	0.487	4,430	110	0.653	0.000	0.653	5,780	113
North Hampton1/	w/Hampton						(.521)	0.000	(.521)	7,890	66	(.969)	0.000	(.969)	13,650	71	(1.366)	0.000	(1.366)	18,460	74	(1.862)	0.000	(1.862)	24,180	77	(2.305)	0.000	(2.305)	28,810	80
Portsmouth	3.800	36,480	104	4.200	39,000	108	3.973	0.689	4.662	42,270	110	4.724	0.727	5.451	47,710	114	5.533	0.834	6.367	53,710	119	6.312	0.969	7.281	59,550	122	6.906	1.061	7.967	64,020	124
Raymond	0.190	2,395	79	0.160	1,400	114	0.214	0.000	0.214	2,710	79	0.247	0.000	0.247	2,850	87	0.320	0.000	0.320	2,970	108	0.395	0.000	0.395	3,080	128	0.473	0.000	0.473	3,170	149
Rochester	1.500	16,000	94	2.065	18,200	113	2.242	0.387	2.629	20,200	130	2.571	0.456	3.027	20,900	145	2.903	0.567	3.470	21,500	161	3.210	0.703	3.913	21,840	179	3.546	0.833	4.379	22,300	196
Rollinsford	0.076	1,175	65	0.095	1,650	58	0.136	0.002	0.138	2,100	66	0.200	0.002	0.202	2,300	88	0.262	0.002	0.264	2,480	106	0.333	0.003	0.336	2,560	131	0.406	0.003	0.409	2,680	153
Rye1/	w/Hampton and Portsmouth						(.492)	0.000	(.492)	5,230	94	(.790)	0.000	(.790)	7,980	99	(1.805)	0.000	(1.805)	10,530	103	(1.342)	0.000	(1.342)	12,660	106	(1.576)	0.000	(1.576)	14,590	108
Salem	1.382	16,606	83	1.560	22,540	69	3.007	0.073	3.080	31,000	99	3.692	0.083	3.775	35,500	106	4.320	0.097	4.417	40,000	110	4.570	0.111	4.681	40,800	115	4.730	0.118	4.848	40,430	120
Seabrook2/	0.273	3,900	70	0.620	6,240	99	0.493	0.397	0.890	7,170	124	0.798	0.529	1.327	9,680	137	1.059	0.710	1.769	11,810	150	1.165	0.948	2.113	11,900	178	1.139	1.210	2.349	9,730	241
Somersworth	0.950	8,000	119	1.400	8,500	165	1.210	0.458	1.668	9,450	177	1.440	0.426	1.866	9,600	194	1.583	0.495	2.078	9,650	215	1.768	0.565	2.351	10,150	232	1.998	0.593	2.591	10,800	240
Wakefield	0.090	700	129	0.150	675	222	0.162	0.000	0.162	980	165	0.185	0.000	0.185	1,020	181	0.203	0.000	0.203	1,050	193	0.214	0.000	0.214	1,050	204	0.232	0.000	0.232	1,090	213
TOTALS	13.695	148,601	92	16.922	173,366	98	18.709	2.629	21.338	200,015	107	23.463	2.914	26.377	235,495	112	25.779	3.528	30.914	257,045	120	31.170	4.273	35.443	281,585	126	34.791	4.913	39.704	298,165	133
GRAND TOTAL	13.695	148,601	92	16.922	173,366	98	19.996	2.629	22.628	219,405	103	26.514	2.914	29.428	271,285	108	31.089	3.528	36.224	309,075	117	38.953	4.273	43.226	348,855	124	44.866	4.913	49.779	374,615	133

1/ Demand Figures in Parenthesis are included in Suppliers' Totals.

2/ Served Population Figures Average Peak Summer Populations over the Entire Year.

TOTAL, MUNICIPALLY SUPPLIED WATER DEMAND ESTIMATES

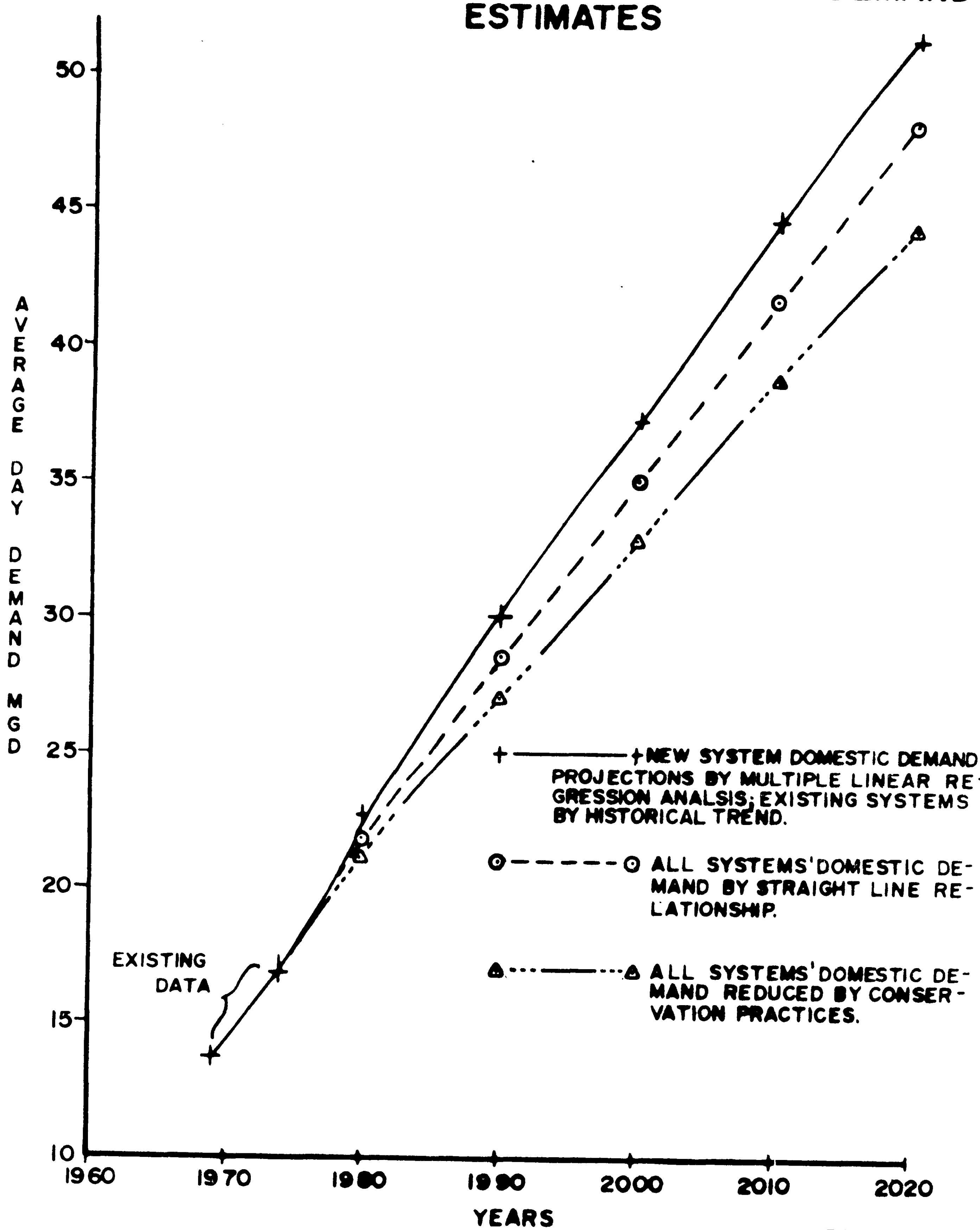


PLATE 5

TABLE II-1[illegible]

POPULATION AND DEMAND COMPARISONS

Year	Corps of Engineers Report: Total Population	Served Population	Total Demand	Percent Served	GPCD	Statewide Study: Total Population	Served Population	Total Demand	Percent Served	GPCD
1980	244,240	219,405	22.7	90	104	261,800	246,200	26.2	94	106
1990	291,930	271,285	29.4	93	108	351,400	338,200	44.2	96	131
2000	331,410	309,075	36.2	93	117	472,200	470,000	71.7	100	153
2010	368,210	348,855	43.2	95	124	6[illegible]9,000	637,200	112.4	100	176
2020	402,160	374,615	49.8	93	133	865,100	864,100	167.9	100	194

III. PHYSICAL DATA

A. The Hydrologic Cycle

Precipitation, percolation, run-off, evaporation and transpiration are stages in, and together comprise the continuous process known as the hydrologic cycle. The sun provides the energy for this cycle, and gravity the direction of flow. Plate 6 illustrates the five stages of the hydrologic cycle.

Within the study area, approximately 40 inches of water per year falls to the ground in some form of precipitation. This precipitation, over a long term falls at a fairly uniform rate throughout the year - a little over 3 inches per month. Of this amount, approximately half, or 20 inches either flows overland into surface water bodies or percolates through the ground to the water table. (The summer is "drier" than the other seasons because although the rainfall is approximately even throughout the year, transpiration, plant uptake and evaporation are highest in the summer and that is when most of the 20 inches of water is withdrawn from the water budget.) Most groundwater eventually discharges at the earth's surface through springs or passes into surface water bodies. Groundwater seepage makes up the dry weather flows of streams and brooks.

Although groundwater and surface water will be discussed separately in the following sections, it is important to realize the interrelationship and interdependence of these components of the water system.

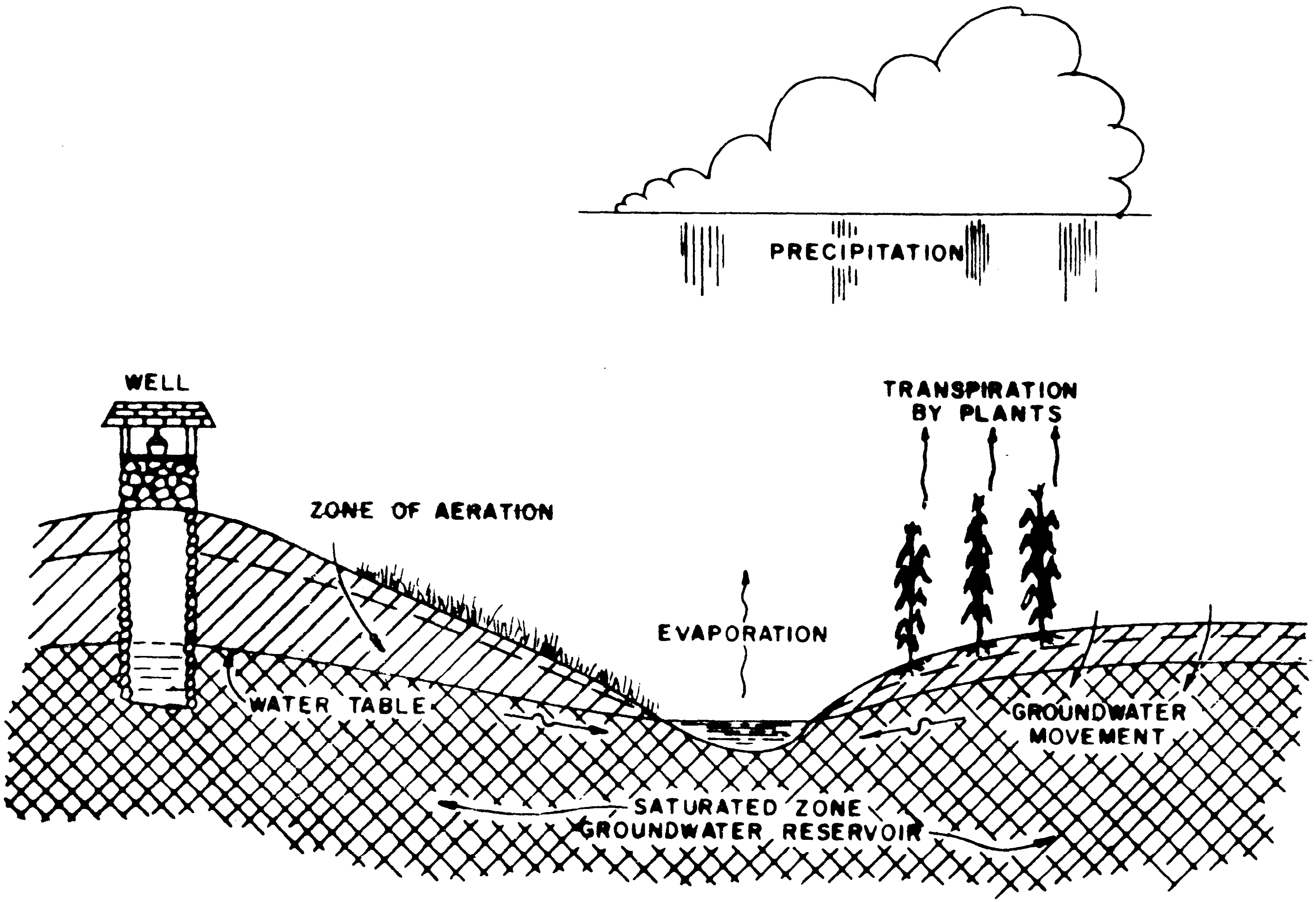
B. Groundwater Availability

1. Purpose and Scope

The purpose of this section of the report is to arrive at a quantative estimate of the sustained groundwater supply for southeastern New Hampshire. The scope of work involved the analysis and interpretation of existing groundwater favorability maps and reports, geologic and hydrogeologic maps and reports, soils surveys, and topographic maps of the area. Field work, geologic mapping, well drilling and pump testing were beyond the scope of this investigation.

2. Physiography

The geology of the area consists of unconsolidated deposits of glacial and recent origin overlying crystalline metamorphic and plutonic rocks of generally early paleozoic age. The glacial deposits



THE HYDROLOGIC CYCLE

PLATE 6

were formed during the most recent stage of the Pliestocene epoch as the ice front advanced over the area north and subsequently retreated when the climate changed and temperatures rose. As the ice advanced slowly over the land it eroded and transported vast quantities of rock material.

That portion of the eroded material which was deposited directly from the ice as it moved over the land is called till and is generally seen as a compact poorly sorted sediment consisting of clayey silt and sand with some gravel and larger rocks. The till in the study area, also known as "hard pan", is commonly less than 15 feet in thickness and exhibits low permeability. Water lain sediments in the area deposited by water melting off of the wasting ice are termed stratified drift deposits and are of several types. Ice contact deposits are laid down by melt water on or next to blocks of stagnant glacial ice and, in this study area, generally consist of stratified sands and gravels ranging in thickness from less than one foot to greater than 190 feet. Outwash is formed from melt water streams depositing glacial sediments in front of the margin of the wasting ice sheet. These sediments are generally finer in grain size and form thinner deposits than are seen in ice contact deposits. Pleistocene marine shore deposits, formed as the sea rose and re-advanced over the land in response to glacial melting, are similar in lithology, texture and appearance to outwash deposits. Recent deposits consist chiefly of a thin layer of eolian sediments, alluvial material, and recent beach deposits. The topography of the eastern half of the study area is of generally low relief with only scattered local outcrops of bedrock. In this area pleistocene marine shore deposits are widespread, commonly resting on till or bedrock and occasionally overlain by, or inter-bedded with, ice contact and outwash deposits. In the western part of the study area the relief is more pronounced with bedrock outcrops and thinly veneered hills and ridges of bedrock prominant. Marine deposits do not extend more than approximately 20 miles inland or above the 200 foot contour line.

Several sources of information within the scope of this investigation were available. Groundwater favorability maps for 18 of the communities in the east central part of the area were provided by the New Hampshire Office of Comprehensive Planning and the Strafford-Rockingham Regional Council. This source of information is designated as RPC in Table III-1. Surficial geologic maps and groundwater information for parts or all of an additional 11 communities is contained in a Water Supply Paper on southeastern New Hampshire (Bradley, 1964) and is designated on Table III-1 as Bradley. Soil surveys of Rockingham County (Van der Voet, 1959) and Strafford County (Shearin, 1949) were used as sources for parts or all of another 14 communities and are identified by the code SCS on Table III-1. Sources for parts or all of the other 5 communities, with identifying codes underlined, are papers or reports by the following: Weigle; Goldthwaite; and SNHRPC (Southeastern New Hampshire Regional Planning Commission, 1975). In addition to the above sources, a set of USGS topographic maps covering the area were also used.

3. Compilation of Data

a. Methodology

The methods adopted for this report consisted of identifying and delineating areas of potentially high groundwater yield on maps and then determining the size of that area in order to quantify the sustained yield expected. The only aquifers in the study area judged capable of producing high sustained yields are those consisting of ice contact drift deposits of sufficient size and thickness. The ideal requirements for a safe yield of 100,000 gpd are an ice contact deposit of at least one tenth of a square mile in surface area and a saturated thickness of no less than 50 feet. Since the scope of this project precluded any field work, the results compiled were necessarily based on interpretations of existing published material. Furthermore, not all the literature available concerned itself with groundwater potential or even sub-surface geologic information and thus there were different levels of source material reliability. Identification of these levels and the modification of the basic methodology where deemed appropriate in order to offset low reliability information is reported below.

The RPC maps and the work of Bradley were both considered reliable with the RPC maps having a higher level of confidence since they were refined from Bradley's work, on the basis of additional pumping data. In the case of the RPC maps, areas considered to be of high groundwater potential were already delineated and they were accepted without further investigation. Bradley's surficial maps were examined and areas of ice contact drift were noted and delineated providing they were of sufficient areal extent. Unless there was strong implicit or explicit evidence from other sources to the contrary, these deposits were assumed to be of the necessary thickness. The SCS maps were judged as low in reliability for determining groundwater capability since the information reported was based on study of surface soils rather than sub-surface geology. Soils mapped on the SCS reports as being composed of bedded sands and gravels, having good to excessive drainage, and exhibiting kame or terrace topography, were considered as favorable for groundwater availability. Soil series in this favorable category include Hinckley, Jaffrey, Merrimac and Barnstead soils. Areas of these soils large enough in size to be practical were outlined on topographic maps. The remaining references cited, usually covering only one or two towns, were considered generally reliable because they contained either geologic or groundwater information which could then be used in a manner similar to that employed with the work of Bradley and the RPC maps discussed previously.

b. Analysis

The areas shown on Plate 5 delineated for groundwater favorability on the various maps were measured with a polar planimeter and the results were expressed in units of square miles. An estimate of a sustained yield of one million gallons per day from each square mile of high potential aquifer was the guideline used in this report. Thus, 1 square mile is predicted to yield 1 mgd, 0.1 square miles will yield 100,000 gpd, and so forth. In an attempt to offset the low reliability of the SCS maps, a more conservative estimate of only 500,000 gpd (0.5 mgd) from each square mile of land outlined as favorable on the soils maps was used.

In general, no area smaller than 0.1 square mile was included in the results of this report. Areas smaller than this minimum size would produce less than 100,000 gpd and thus not be compatible with plans for future municipal water supply. However, where there were two or more smaller plots in close proximity to each other (less than 1,000 feet), whose total area exceeded 0.1 square mile, they were included in the totals given on Table III-1. The total of all groundwater areas within a community and the total estimated safe yields are listed on Table III-1.

Where a parcel of favorable land overlapped town boundaries the area of that parcel is usually listed as one number and included with the town that contains the largest segment of that parcel.

With respect to areas delineated from SCS maps, only those larger than about 0.35 square miles were selected for inclusion in this report. An area of this size multiplied by the conversion factor of 0.5 mgd per square mile adopted for SCS maps would yield 175,000 gpd. The larger minimum area was used in accord with the more conservative guidelines employed when dealing with SCS materials.

4. Results

The results of the investigation and analysis are displayed in Table III-1 and graphically on Plate 7. Next to each community name there is listed the following information about that community: source material, total selected land area and estimated safe yield. The total area of sites identified in the 47 communities equaled 63 square miles and the total estimated safe yield is 58 million gallons per day.

C. Surface Water

1. Hydraulic Data of the Major Streams

Communities within the study area lie within four major river basins, the Merrimack, New Hampshire Coastal, Piscataqua and the Saco. Of these four basins, the Saco River Basin comprises the smallest portion draining only 16 square miles of Wakefield. The New Hampshire Coastal Basin is the next smallest, draining approximately 55 square miles of the study area. Approximately 173 square miles of the study area drain into the Merrimack River. The largest portion of the study area - 755 square miles - is drained by the Piscataqua River. The major tributary basins of the Piscataqua River have been delineated and are shown on Plate 8. Table III-2 lists the four major drainage basins and the delineated sub-basins of the Piscataqua, with the community areas and total areas drained by each.

The two basins of major concern in this report are Piscataqua and New Hampshire Coastal, which together account for 831 square miles or 83 percent of the 1,000 square mile study area. The Piscataqua River Basin is bounded on the Northeast by the Maine Coastal Area; on the north by Saco River Basin; the west and south by the Merrimack River Basin; and on the east by the New Hampshire Coastal Area. The New Hampshire Coastal Basin is likewise bound on the north and west by the Piscataqua River Basin and on the south by the Merrimack River Basin.

There are seven major streams draining the study area: the Bellamy, Cocheco, Exeter, Lamprey, Oyster, Piscataqua and Salmon Falls Rivers. All of these rivers lie within the Piscataqua River Basin. The Salmon Falls and Piscataqua Rivers form the New Hampshire-Maine State boundary. Three of these streams - the Exeter, Lamprey and Oyster Rivers - are tributary to Great Bay; the Bellamy River is tributary to Little Bay and the bays flow northward - Great to Little - and empty into the Piscataqua River. The Piscataqua River, formed by the confluence of the Cocheco and Salmon Falls Rivers is completely tidal, as are Great and Little Bays. A brief description of each of these rivers follows:

TABLE III-1

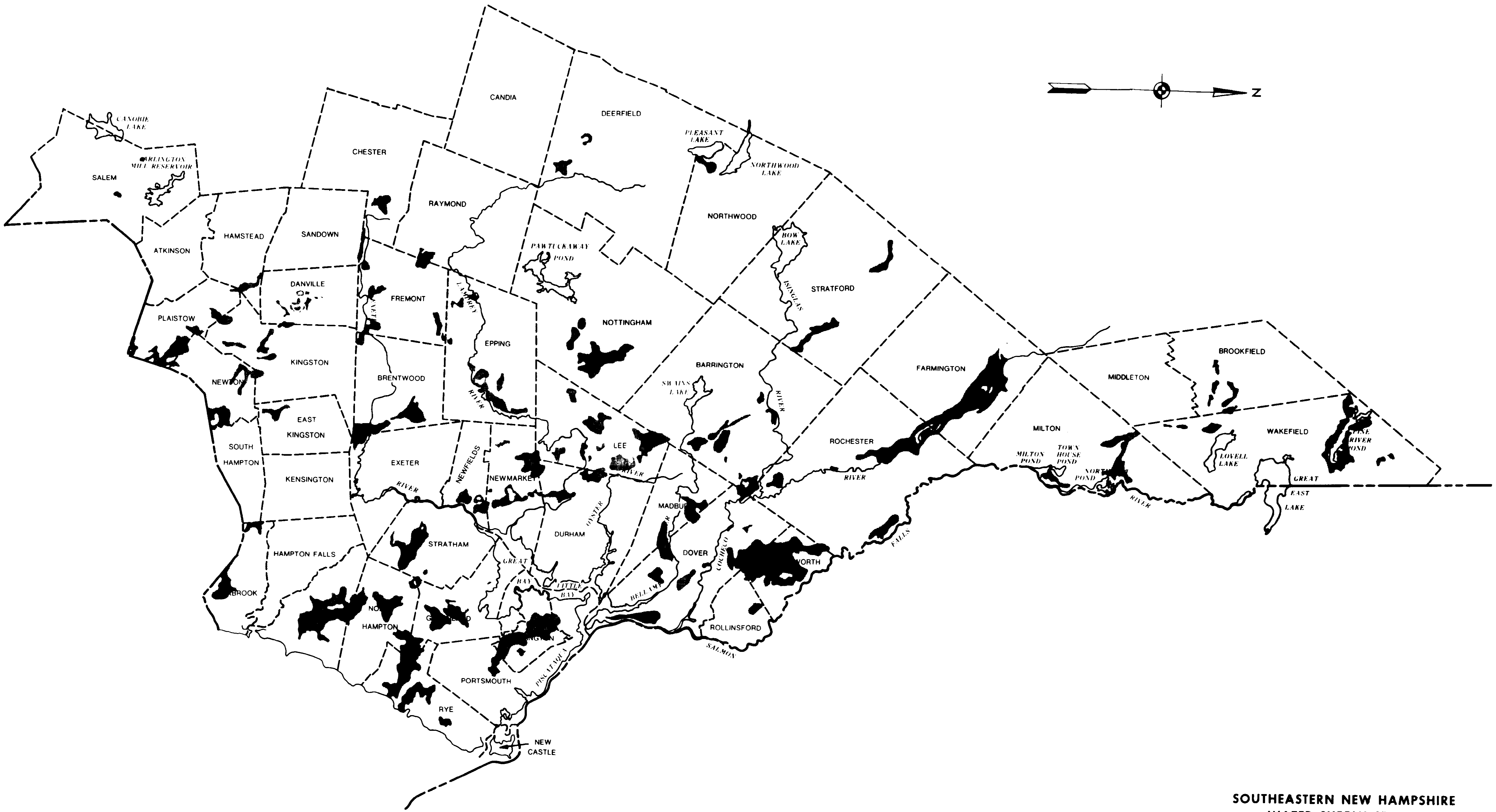
ESTIMATED GROUNDWATER POTENTIAL

Community	Source	Total Area (mi^2)	Safe Yield (MGD)
Atkinson	Bradley/Weigle		
Barrington	SCS/Bradley	2.44	1.80
Brentwood	Bradley	1.31	1.31
Brookfield	Goldthwait	0.78	0.78
Candia	SCS		
Chester	SCS	0.39	0.20
Danville	SCS	0.54	0.27
Deerfield	SCS	0.36	0.18
Dover	RPC	1.46	0.73
Durham	RPC		
East Kingston	Bradley	0.53	0.53
Epping	SCS/SNHRPC	1.24	0.94
Exeter	RPC	0.72	0.71
Farmington	Bradley	4.25	4.25
Fremont	SCS	2.16	1.08
Greenland	RPC	1.39	1.39
Hampstead	SCS	0.36	0.18
Hampton	RPC	3.79	3.79
Hampton Falls	RPC		
Kensington	Bradley	2.02	2.02
Kingston	Bradley	1.34	1.34
Lee	RPC	3.51	3.51
Madbury	RPC	1.48	1.48
Middleton	SCS		
Milton	SCS	1.69	0.84
Newfields	RPC	0.82	0.82
Newton	Bradley	1.19	1.19

TABLE III-1 (Cont'd)

ESTIMATED GROUNDWATER POTENTIAL

Community	Source	Total Area (mi^2)	Safe Yield (MGD)
Newington	RPC	1.36	1.36
New Market	RPC	1.17	1.17
North Hampton	RPC	0.88	0.88
Northwood	SCS		
Nottingham	RPC	2.86	2.86
Plaistow	Bradley	1.64	1.64
Portsmouth	RPC	1.50	1.50
Raymond	SCS		
Rollinsford	RPC		
Rochester	Bradley	3.94	3.94
Rye	RPC	3.10	3.10
Salem	Weigle	0.14	0.14
Sandown	SCS		
Seabrook	RPC	1.22	1.22
Somersworth	RPC	6.18	6.18
South Hampton	Bradley	0.26	0.26
Strafford	SCS	1.22	0.61
Stratham	RPC	1.50	1.50
Wakefield	Goldthwait	2.33	2.33
	TOTALS	63.05	58.02



SOUTHEASTERN NEW HAMPSHIRE
WATER SUPPLY STUDY

GROUNDWATER AQUIFER LOCATIONS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7

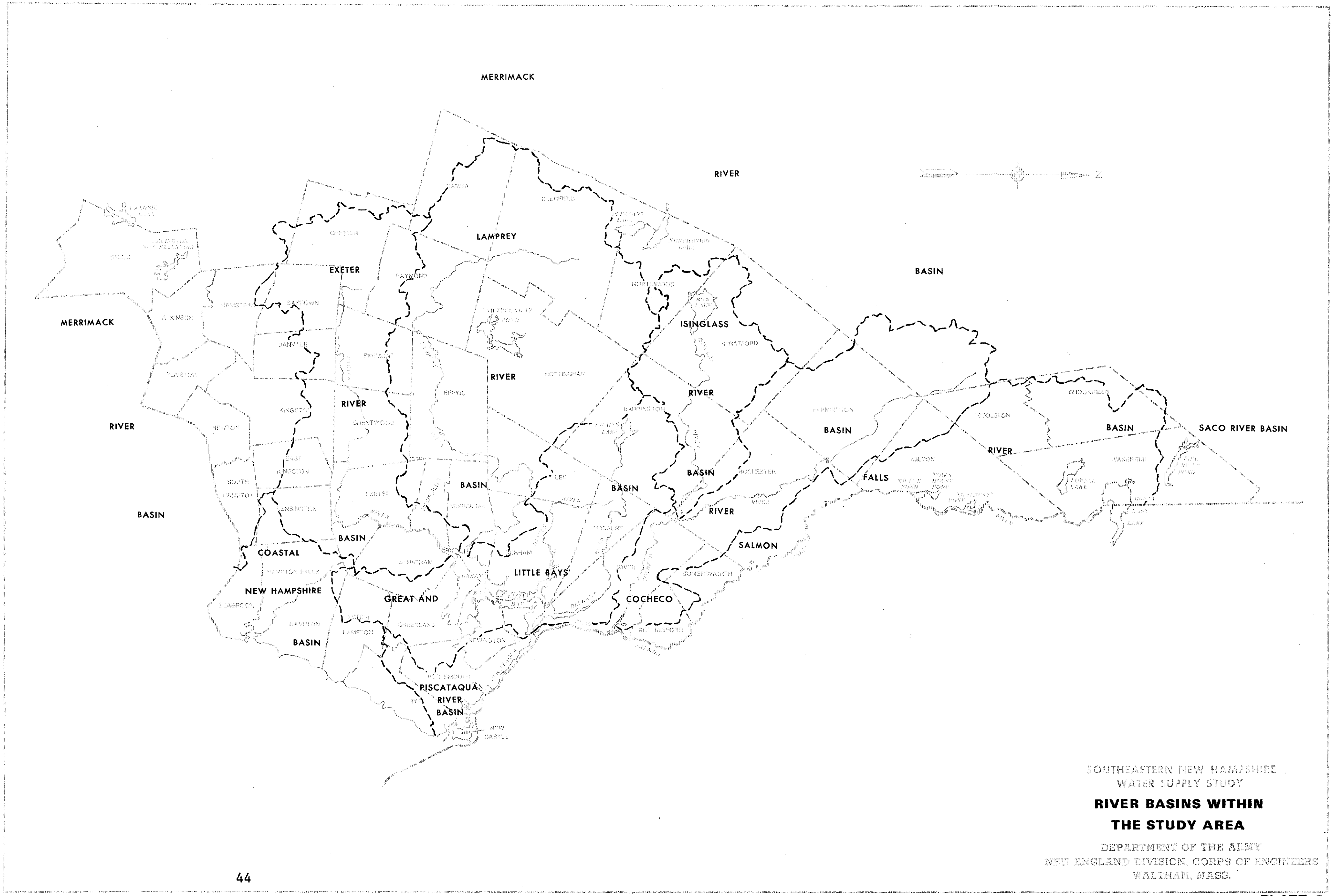

MERRIMACK
RIVER
BASIN
MERRIMACK
RIVER
BASIN
LAMPREY
RIVER
BASIN
EXETER
RIVER
BASIN
ISINGLASS
RIVER
BASIN
BASIN
FALLS
RIVER
BASIN
SALMON
RIVER
SACO RIVER BASIN
COASTAL
NEW HAMPSHIRE
BASIN
GREAT AND
LITTLE BAYS'
BASIN
COCHECO
PISCATAQUA
RIVER
BASIN
SOUTHEASTERN NEW HAMPSHIRE
WATER SUPPLY STUDY
RIVER BASINS WITHIN
THE STUDY AREA
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 8

TABLE III-2

STUDY AREA RIVER BASIN DRAINAGE AREAS, BY COMMUNITY

	Percent of Community's Total Area	Square Miles
A. Saco River Basin		
Wakefield	36.0	16.2
Basin Total		16.2
B. Coastal Basin		
Exeter	1.8	0.4
Hampton	94.1	12.7
Hampton Falls	94.2	11.8
Kensington	28.9	3.4
North Hampton	58.3	8.0
Rye	65.8	9.2
Seabrook	96.6	9.2
South Hampton	1.3	0.1
Basin Total		54.8
C. Merrimack River Basin		
Atkinson	100.0	11.0
Brookfield	18.9	4.4
Candia	33.1	10.0
Chester	27.5	7.2
Danville	63.2	7.4
Deerfield	18.2	9.4
East Kingston	64.6	6.4
Farmington	7.2	2.7
Hampstead	94.1	13.6
Kensington	8.1	1.0
Kingston	73.3	15.2
Middleton	0.9	0.2
Newton	100.0	9.9
Northwood	44.4	13.2
Plaistow	100.0	10.5

TABLE III-2 (Cont'd)

STUDY AREA RIVER BASIN DRAINAGE AREAS, BY COMMUNITY

	Percent of Community's Total Area	Square Miles
C. Merrimack River Basin (Cont'd)		
Salem	100.0	25.6
Sandown	15.4	2.2
Seabrook	3.4	0.3
South Hampton	98.7	7.8
Stratford	29.3	15.2
Basin Total		173.2
D. Piscataqua River Basin		
Greenland	4.6	0.6
New Castle	100.0	2.0
Newington	26.5	3.2
Portsmouth	74.4	11.6
Rye	34.2	4.8
Basin Sub-Total		22.2
1. Salmon Falls River Basin		
Brookfield	81.1	19.0
Dover	3.6	1.0
Farmington	1.1	0.4
Middleton	76.6	14.2
Milton	85.1	29.5
Rochester	24.8	11.6
Rollinsford	41.3	3.2
Somersworth	60.9	6.3
Wakefield	64.0	28.8
Basin Sub-Total		114.0

TABLE III-2 (Cont'd)

STUDY AREA RIVER BASIN DRAINAGE AREAS, BY COMMUNITY

	Percent of Community's Total Area	Square Miles
D. Piscataqua River Basin (Cont'd)		
2. Cocheco River Basin		
Barrington	0.9	0.4
Dover	52.8	14.9
Farmington	91.7	34.3
Madbury	2.4	0.3
Middleton	22.5	4.2
Milton	14.9	5.2
Rochester	64.5	30.3
Rollingsford	58.7	4.5
Somersworth	39.1	4.0
Stratford	6.3	3.3
Basin Sub-Total		101.4
3. Isinglass River Basin		
Barrington	43.6	21.4
Northwood	15.0	4.5
Rochester	10.7	5.0
Stratford	64.3	33.4
Basin Sub-Total		64.3
4. Lamprey River Basin		
Barrington	10.9	5.3
Brentwood	10.6	1.7
Candia	64.2	19.4
Deerfield	81.8	42.5
Durham	25.6	6.5
Epping	100.0	26.2
Exeter	12.5	2.4
Fremont	27.3	4.7

TABLE III-2 (Cont'd)

STUDY AREA RIVER BASIN DRAINAGE AREAS, BY COMMUNITY

	Percent of Community's Total Area	Square Miles
D. Piscataqua River Basin (Cont'd)		
Lee	63.3	12.9
Newfields	57.7	4.2
New Market	73.7	10.2
Northwood	40.6	12.1
Nottingham	99.0	47.6
Raymond	65.9	19.3
Stratford	0.1	0.1
Basin Sub-Total		215.1
5. Exeter River Basin		
Brentwood	89.4	15.1
Candia	2.7	0.8
Chester	72.5	18.8
Danville	36.8	4.3
East Kingston	35.4	3.5
Exeter	85.0	16.6
Fremont	72.7	12.5
Hampstead	5.9	0.8
Hampton Falls	5.8	0.7
Kensington	63.0	7.4
Kingston	26.7	5.6
Newfields	42.3	3.1
New Market	9.9	1.4
Raymond	34.1	10.0
Sandown	84.6	12.1
Stratham	66.3	10.1
Basin Sub-Total		122.8

TABLE III-2 (Cont'd)

STUDY AREA RIVER BASIN DRAINAGE AREAS, BY COMMUNITY

	Percent of Community's Total Area	Square Miles
D. Piscataqua River Basin (Cont'd)		
6. Great & Little Bays Basin		
Barrington	44.6	21.8
Dover	43.6	12.3
Durham	74.4	19.0
Exeter	0.7	0.1
Greenland	95.4	13.0
Hampton	5.9	0.8
Lee	36.7	7.5
Madbury	97.6	13.7
Newington	73.5	8.9
New Market	16.4	2.3
North Hampton	41.7	5.8
Nottingham	1.0	0.5
Portsmouth	25.6	4.0
Stratham	33.7	5.1
Basin Sub-Total		114.8
Basin Total		754.6
Study Area Total		998.8

1. Bellamy River - Rises in Swains Pond in Barrington, New Hampshire and flows easterly to the Bellamy Reservoir, a water supply reservoir for Portsmouth, and continues easterly to Dover. At Dover, the river flows south to its mouth at Cedar Point in Little Bay. The river's total watershed is 35 square miles, and the four mile stretch from Dover to Little Bay is completely tidal.

2. Cocheco River - Rises in New Durham, New Hampshire in the southern slope of Birch Ridge. The river flows in a southeasterly direction for 34 miles to its confluence with the Salmon Falls River in Dover, New Hampshire. The total watershed of the river is 180 square miles and the lowest 2.8 miles are tidal. The Isinglass River, which rises in Bow Lake, is a major tributary of the Cocheco River. It has a total length of approximately 14.5 miles, and drains an area of approximately 64 square miles.

3. Exeter River - Rises in Chester, New Hampshire and flows easterly to Exeter where it turns north and flows into Great Bay. The total watershed area is 129 square miles, and the lower 7 river miles are tidal. (The tidal portion of the Exeter River is known as the Squamscott River.)

4. Lamprey River - Rises in Northwood, New Hampshire and flows easterly to Epping, northeasterly to Durham, then southeasterly to its mouth in Great Bay in Newmarket. The total length of the river is 42 miles and it has a total watershed of 211 square miles. The river is tidal from Newmarket to Great Bay.

5. Oyster River - Rises in Barrington, New Hampshire and flows southeasterly to Durham, emptying into Great Bay at Durham Point. The river is tidal to the tidehead dam in Durham, and has a total watershed of 32 square miles.

6. Piscataqua River - Formed by the confluence of the Cocheco and Salmon Falls Rivers, it flows southerly for 4 miles and then southeasterly for approximately 9 miles to its mouth in the Atlantic Ocean. The entire river is tidal, and approximately 9 miles above its mouth receives flow from Great and Little Bays.

7. Salmon Falls River - Rises in Great East Lake in Wakefield, New Hampshire and Acton, Maine and flows southerly 36.5 miles to its confluence with the Cocheco River. The total watershed of the river is 330 square miles of which 114 square miles are in New Hampshire. The lower 3.7 miles of the river are tidal.

The United States Geological Survey maintains gaging stations on many of the nation's rivers and streams. Five such stations are located within the study area. The Salmon Falls, Oyster and Lamprey Rivers are gaged, as are Dudley and Mohawk Brooks. The stations on the three rivers have been in operation long enough to have generated sufficient data for statistical analysis and estimation of low flow duration curves. These curves, based on USGS data, are presented as Plates 9, 10, 11 and illustrate the percent chance of occurrence of a flow of a certain magnitude and duration. For example, on Plate 9 "Low Flow Duration Curves, Lamprey River, Newmarket, New Hampshire" a flow of 0.75 cfs for 1 day has a 50 percent chance of occurrence.

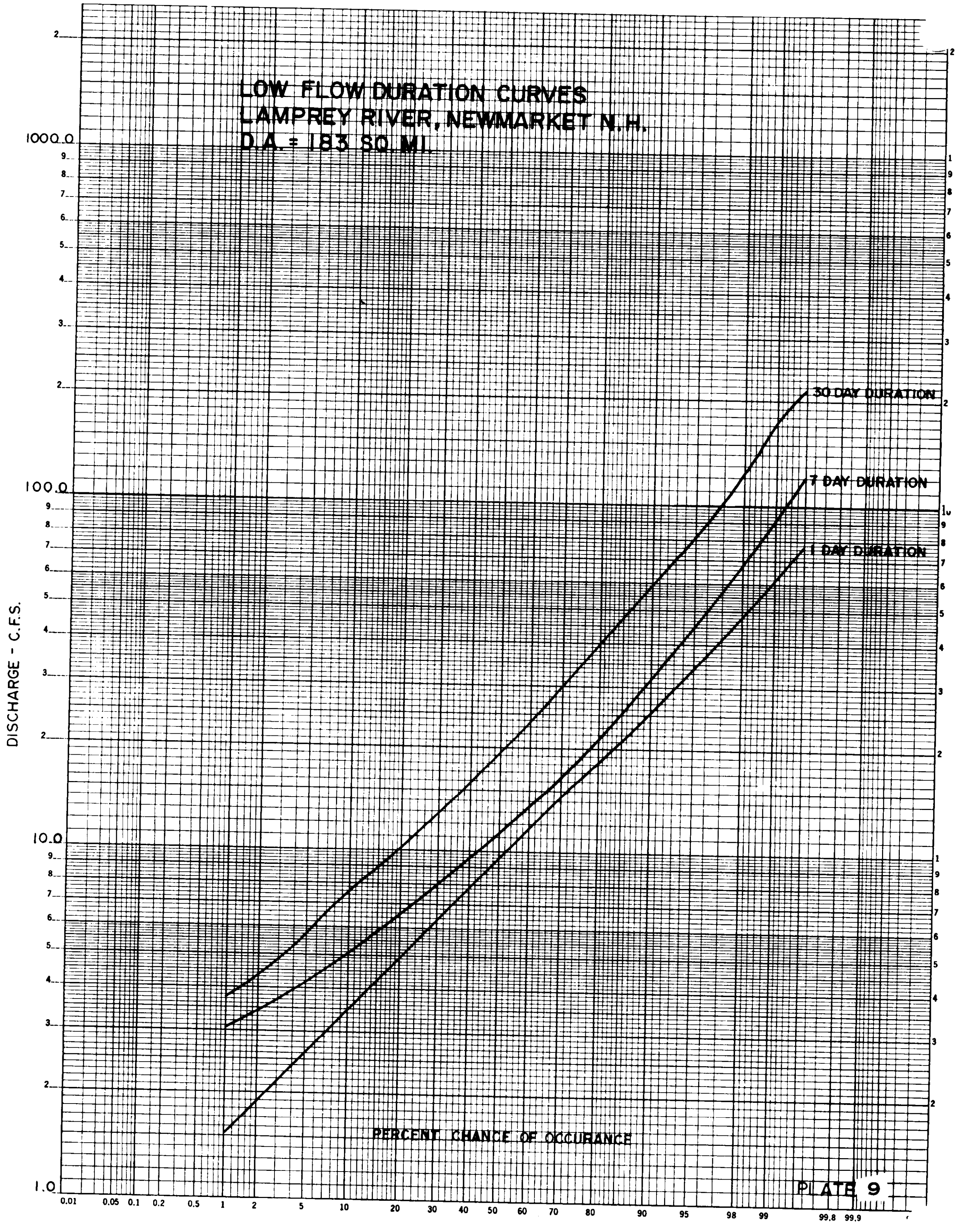
These curves are interesting because they indicate the low flow regimes of the region's rivers. For water supply purposes, without storage, the lowest daily flow is the safe yield of a stream. With storage, however, a flow approaching the mean annual flow may be developed provided it is economically, environmentally, and technically feasible. The minimum daily flows recorded at these gaging stations with a 5 percent chance of occurrence range from a low of about 4 on the Oyster River near Durham to a high of about 8.2 cfs on the Salmon Falls River. On a 7-day basis and a 20-year return interval, the figures range from about 0.5 cfs on the Oyster River to about 28 cfs on the Salmon Falls River. As discussed later, many of these streams' natural flows are too low to support water supply needs. Therefore, storage is required if local surface waters are to be used for water supply purposes to meet the region's future needs.

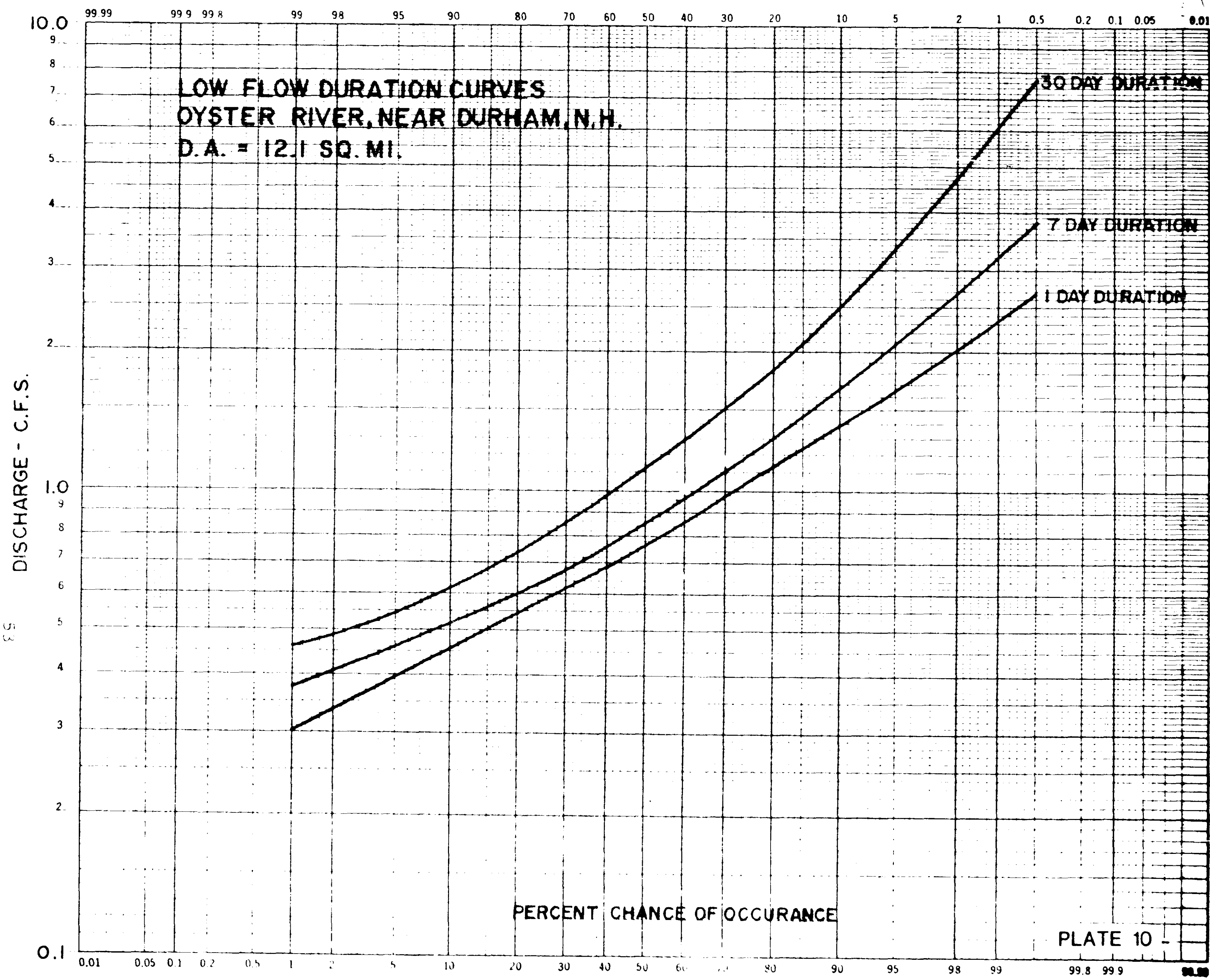
2. Possible Reservoir Locations

The Soil Conservation Service of the U.S. Department of Agriculture has selected a total of 49 possible dam and reservoir locations within the study area as a portion of the North Atlantic Regional (NAR) Water Resources Study. A summary of these sites with total water stored, benefits and costs can be found in Appendix F of NAR Study. These 49 sites are in addition to the Bellamy Reservoir and include the site on the Isinglass River proposed in an earlier consultants' report[1] for the seacoast region.

The amount of storage varies significantly, as do the preliminary cost estimates made for the NAR Study. All 49 sites are shown on Plate 12 and Table III-3, lists each site in numerical order, its major and minor basins, the name of the impounded stream, drainage area, storage capacity, surface area and dam height. No attempt was

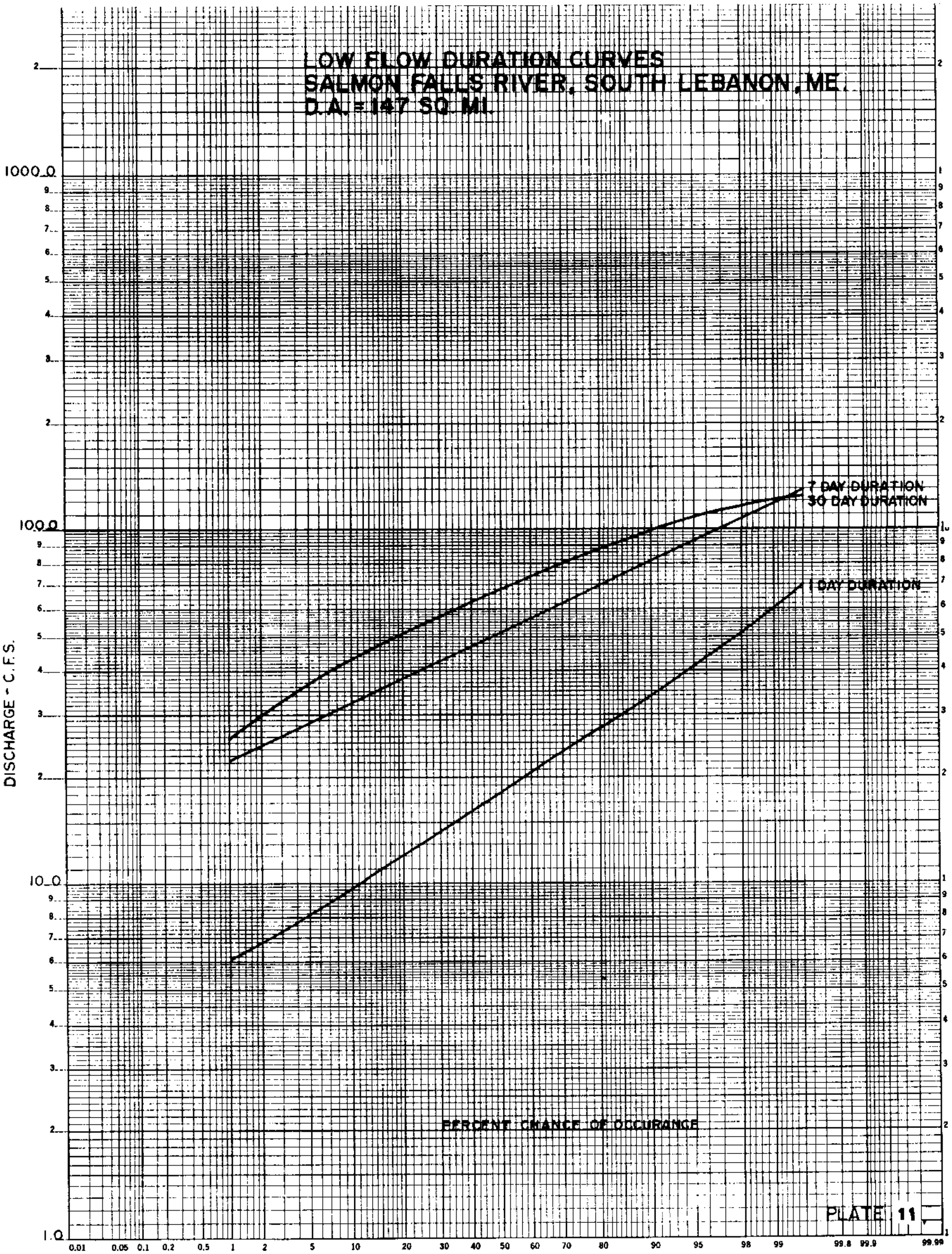
[1] New Hampshire Water Resources Board Report Metropolitan Water Supply For Seacost Area; Camp, Dresser & McKee, October, 1960.

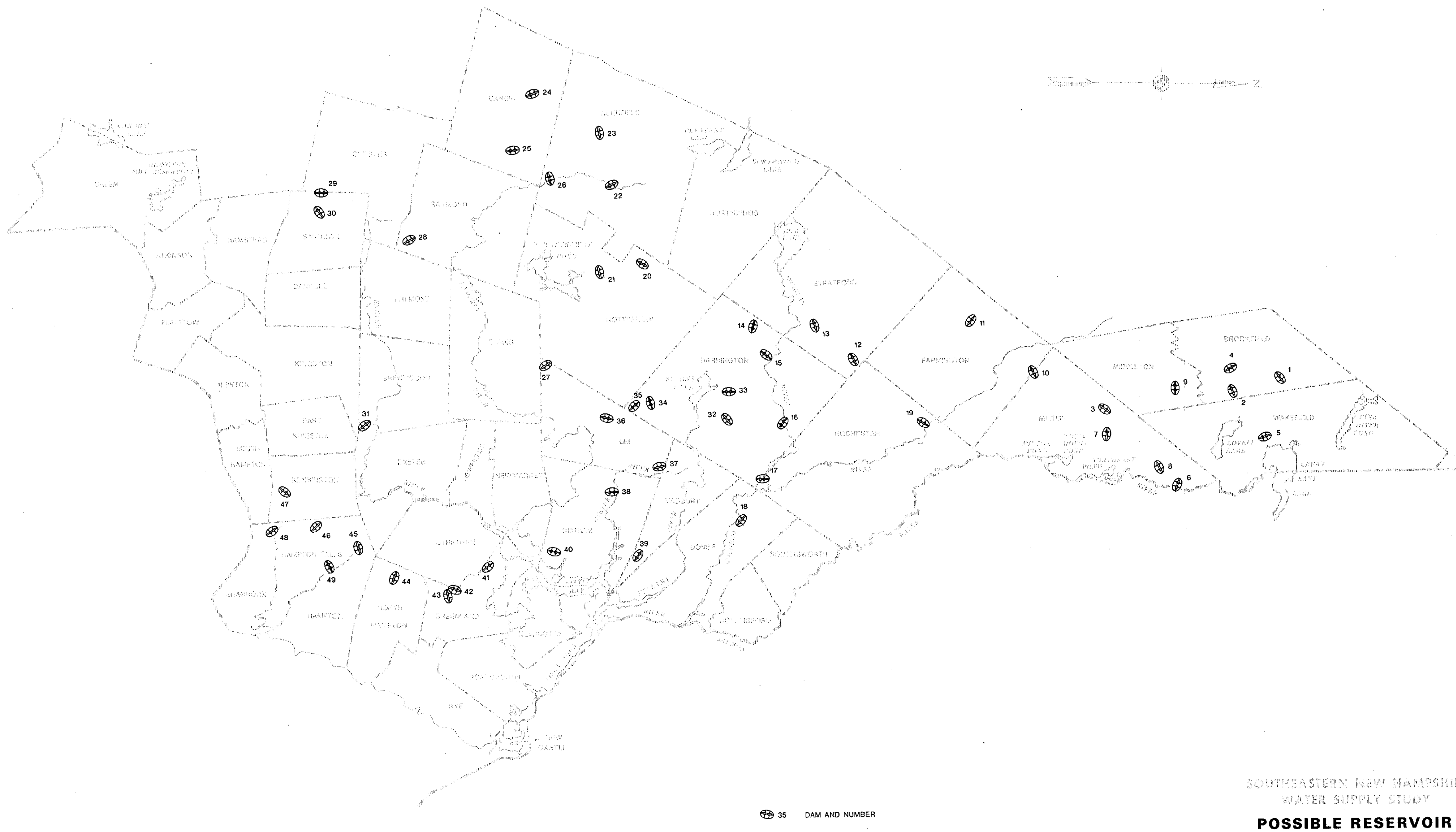

LOW FLOW DURATION CURVES
LAMPREY RIVER, NEWMARKET N.H.
D.A. = 183 SQ. MI.
30 DAY DURATION
7 DAY DURATION
1 DAY DURATION
DISCHARGE - C.F.S.
PERCENT CHANCE OF OCCURANCE
PLATE 9



LOW FLOW DURATION CURVES
OYSTER RIVER, NEAR DURHAM, N.H.
D.A. = 12.1 SQ. MI.
30 DAY DURATION
7 DAY DURATION
1 DAY DURATION
DISCHARGE - C.F.S.
PERCENT CHANCE OF OCCURANCE

PLATE 10


LOW FLOW DURATION CURVES
SALMON FALLS RIVER, SOUTH LEBANON, ME.
D.A. = 147 SQ. MI.
7 DAY DURATION
30 DAY DURATION
1 DAY DURATION
DISCHARGE - C.F.S.
PERCENT CHANCE OF OCCURANCE
1000.0
100.0
10.0
1.0
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PLATE 11



SOUTHEASTERN NEW HAMPSHIRE
WATER SUPPLY STUDY

POSSIBLE RESERVOIR LOCATIONS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 12

TABLE III-3

POSSIBLE RESERVOIR LOCATIONS AND CHARACTERISTICS

No.	Minor Basin	Impoundment Stream	Drain. Area (sq. mi.)	Storage Capacity (Ac Ft)	Surface Area (Ac)	Dam Ht. (Ft.)
		PISCATAQUA RIVER BASIN				
1	Salmon Falls River	Pike Brook	6.89	6,330	400	42
2	Salmon Falls River	Pike Brook	3.40	1,695	175	28
3	Salmon Falls River	Jones Brook	11.09	10,230	540	63
4	Salmon Falls River	Churchill Brook	7.07	1,620	84	46
5	Salmon Falls River	Copp Brook	3.35	2,734	357	27
6	Salmon Falls River	Salmon Falls River	23.84	22,000	1,030	51
7	Salmon Falls River	Branch River Tributary	4.84	4,468	275	35
8	Salmon Falls River	Miller Brook	3.07	866	41	41
9	Salmon Falls River	Branch River Tributary	0.53	495	23	51
10	Cocheco River	Dames Brook	14.39	13,350	800	63
11	Cocheco River	Mad River	7.47	2,340	124	57
12	Cocheco River	Berrys River	7.45	6,880	400	47
13	Cocheco River	Isinglass River Tributary	7.51	6,920	410	66
14	Cocheco River	Stonehouse Brook	6.37	5,872	400	42
15	Cocheco River	Isinglass River	55.31	51,135	1,750	77
16	Cocheco River	Isinglass River	7.80	7,189	295	41
17	Cocheco River	Isinglass River	8.47	5,995	400	53
18	Cocheco River	Reyners Brook	2.20	2,030	130	43
19	Cocheco River	Cocheco River	35.40	18,000	1,000	55
20	Lamprey River	Beach River	4.01	3,200	120	43
21	Lamprey River	Pack Creek	7.30	5,850	500	57
22	Lamprey River	Lamprey River	10.64	4,600	210	64
23	Lamprey River	Hartford Brook	5.02	4,000	180	68
24	Lamprey River	North Branch River Trib.	5.40	4,070	182	49
25	Lamprey River	North Branch River	14.45	2,300	180	50
26	Lamprey River	Lamprey River	19.50	3,920	220	39
27	Lamprey River	Lamprey River Trib.	6.80	5,450	440	33
28	Exeter River	Exeter River	35.90	27,400	2,500	41.5
29	Exeter River	Exeter River	5.80	4,420	190	60
30	Exeter River	Exeter River	2.16	1,276	112	31
31	Exeter River	Exeter River	69.20	52,800	2,540	69
32	Great & Little Bays	Mallego Brook	4.86	3,707	370	32
33	Great & Little Bays	Unnamed Brook	1.28	976	81	44
34	Great & Little Bays	Oyster River	1.85	1,411	125	33
35	Great & Little Bays	Caldwell Brook	2.13	1,170	112	36
36	Great & Little Bays	Unnamed Brook	0.22	168	25	20
37	Great & Little Bays	Dube Brook	5.34	2,160	155	48
38	Great & Little Bays	Oyster River	7.80	5,945	440	47
39	Great & Little Bays	Johnson Creek	2.10	1,230	80	42
40	Great & Little Bays	Unnamed Tributary	0.70	534	52	42
41	Great & Little Bays	Brackett Brook	0.55	419	50	22
42	Great & Little Bays	Thompson Brook	1.20	916	90	31
43	Great & Little Bays	Winnicutt River	7.31	5,567	500	36
44	Great & Little Bays	Winnicutt River	4.72	3,596	700	22
		COASTAL BASINS				
45	Hampton River	Ash Brook	1.25	620	50	30
46	Hampton River	Unnamed Brook	1.96	900	250	13
47	Hampton River	Winkley Brook	1.10	646	155	15
48	Hampton River	Hampton Falls River	1.25	735	110	11
49	Hampton River	Taylor River	8.61	4,100	770	28
TOTALS				312,220	20,123	

made to eliminate any sites from consideration at this time, because all sites are technically feasible, although it is recognized that certain sites would require road relocations, interstate cooperation and more extensive land takings than others.

Drainage area and storage capacities are the most important considerations from a supply perspective because the larger the drainage area, the more run-off that can be stored, provided there is the topography to allow for the retention of this run-off. It is well recognized, however, that economic, environmental, social and political considerations can singly or together override the technically most acceptable sites. Such considerations, however, are beyond the scope of this report, and can only be addressed in a more detailed study effort. These considerations would, of course, be made prior to any recommended plan(s) for water supply within the region.

3. Ground-and Surface Water Relationship

The introduction to this Section gave a brief description and illustration of the hydrologic cycle. An important facet of that discussion is the interrelationship of ground and surface water and this must be considered together in any water resource management program which seeks development of the resource.

One local example of this concerns the aquifer underlying Somersworth and a portion of Dover. Both communities, plus at least one industry, use this aquifer as a source of supply. Increased pumping from this aquifer is expected to adversely affect the water levels of Willand Pond which is already classified by the State as a eutrophic lake, therefore, full utilization of that aquifer has been assumed.

Along the Cocheco River in Farmington and Rochester, an aquifer has been identified with a possible safe yield in excess of 7 mgd. Although no gaging stations are reported on the Cocheco River, it has a drainage area of 180 square miles which is approximately equal to the drainage area of the Lamprey River at Newmarket, New Hampshire (183 square miles); and, the Lamprey River has a reported instantaneous minimum flow of 1 cubic foot per second. (1 cfs is approximately equal to 0.6 mgd). Thus, if the Cocheco's low flow approximates the Lamprey's, it is entirely possible that pumping in that aquifer may lower the groundwater table sufficiently to cease flow in the Cocheco during dry weather. In a later section of this report, the entire estimated safe yield of that aquifer is reported available for water supply, however, it is done so with the underlying assumption that groundwater pumping will not lower existing stream low flows. When the possible effect on streamflow is considered this may mean an appreciable decrease in the estimated amount of groundwater available; or a requirement for augmenting stream low flow by upstream storage.

These possible problems can be noted in a study such as this, however, the scope of work, limited time and budget do not allow more than a highlighting of the possible problems. However, it is important to recognize the unity of ground and surface water and the concept of a water budget in the initial stages of a regional water supply study.

4. Water Quality

a. Groundwater

The groundwater quality of the region reportedly varies from aesthetically excellent to aesthetically unacceptable (mainly due to high iron content) and, in at least one instance, potentially hazardous to health due to a high nitrate content. (High nitrates in drinking water can cause methemoglobanemia ("blue baby") if ingested by pregnant women.) In addition to the above, most of the groundwater is moderately hard, and it tends to be corrosive.

The corrosiveness of water can be controlled by chemical addition, and is, therefore, not considered prohibitive to initiating new supply sources from groundwater. Hardness can be reduced, if required, however, this process generates brine and its disposal can present a problem. Some of the groundwater sources have started out with acceptable limits of iron, however, the iron concentration has increased beyond that established as aesthetically acceptable. Iron, while not toxic, can cause color, taste and odor problems if in excess of approximately 0.30 mg/l, and, similarily manganese, if in excess of 0.05 mg/l. The most common treatment method employed in the water works industry for iron reduction is aeration, sedimentation and filtration. These are the same treatment processes required by surface waters, therefore, if a larger safe yield can be obtained from surface supplies, groundwater supplies are generally abandoned if iron and manganese concentrations become too high. This has already occurred in Durham. Exeter has abandoned one well due to high iron concentration, and Dover will use two of its wells only in emergency situations because of high iron concentrations.

For the purposes of this report, the groundwater quality of new well fields has been assumed to be adequate for development. Therefore, in the evaluation of this resource, all water reported earlier as physically available has been assumed available for development.

b. Surface water

The New Hampshire Water Supply and Pollution Control Commission has, through its monitoring programs, classified the present condition of the major streams within the study area which were previously listed, and many of their tributaries. These classifications, and other pertinent data, were published in the 1975 Staff Report No. 67, Piscataqua River and Coastal New Hampshire Basin Water Quality Management Plan, which is the basis of this section of the report.

The State presently recognizes four surface water quality classifications, A, B, C and D, with Class A water acceptable for use as a public water supply after disinfection; Class B water acceptable for body contact sports; Class C acceptable for boating and fishing; and, Class D, aesthetically accetable. Table III-4 lists the four water quality Classes and the requirements for meeting each Class.

All of the State's surface waters have been legally classified, and the monitoring programs and the wastewater collection and treatment programs are all aimed at achieving these legal classifications. All surface water in the State has been legally classified as Class B with the exception of public water supplies, which are Class A, and a few segments of some streams which have been given Class C status due to unique hydraulic and/or pollutional load conditions. No such legal Class C rivers or segments are located within the study area. All surface waters within the study area used as public water supply sources, such as the Bellamy Reservoir, Round Pond and Follets Brook, are all legally Class A waters. In many instances, this legal classification can be viewed as the future water quality goal established by the State.

According to Staff Report No. 67, none of the major streams in the study area presently conform to the legal classification throughout their entire length. The Salmon Falls River fluctuates between Class C and Class D; the Cocheco River is Class D from Farmington to its confluence with the Salmon Falls River; the Bellamy River is Class D in its lower portion; the Oyster River is Class D throughout its length; the Lamprey River is Class C from Raymond to Newmarket; and Class D from Newmarket to Great Bay; and the Exter River changes from Class C to Class D above its tidal portions.

TABLE III-4

RECOMMENDED USE CLASSIFICATIONS [1]
AND
WATER QUALITY STANDARDS
AS OF JANUARY 1, 1970
BASED ON CHAPTER 149 REVISED STATUTES ANNOTATED [2]
NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION

	Class A	Class B	Class C	Class D
	Potentially acceptable for public water supply after disinfection. No discharge of sewage or other wastes. (Quality uniformly excellent).	**Acceptable for bathing and recreation, fish habitat and public water supply after adequate treatment. No disposal of sewage or wastes unless adequately treated. (High aesthetic value).**	**Acceptable for recreational boating, fishing, and industrial water supply with or without treatment, depending on individual requirements. (Third highest quality).**	**Aesthetically acceptable. Suitable for certain industrial purposes, power and navigation.**
Dissolved Oxygen	Not less than 75% Sat.	Not less than 75% Sat.	Not less than 5 p.p.m.	Not less than 2 p.p.m.
Coliform Bacteria per 100 ml	Not more than 50	Not more than 240 in fresh water. Not more than 70 MPN in salt or brackish water.	Not specified	Not specified
pH	Natural	6.5 - 8.0	6.0 - 8.5	Not specified
Substances potentially toxic	None	Not in toxic concentrations or combinations.	Not in toxic concentrations or combinations.	Not in toxic concentrations or combinations.
Sludge deposits	None	Not objectionable kinds or amounts.	Not objectionable kinds or amounts.	Not objectionable kinds or amounts.
Oil and Grease	None	None	Not objectionable kinds or amounts.	Not of unreasonable kind, quantity or duration.
Color	Not to exceed 15 units.	Not in objectionable amounts.	Not in objectionable amounts.	Not of unreasonable kind, quantity or duration.
Turbidity	Not to exceed 5 units.	Not to exceed 10 units in trout water. Not to exceed 25 units in non-trout water.	Not to exceed 10 units in trout water. Not to exceed 25 units in non-trout water.	Not of unreasonable kind, quantity or duration.
Slick, Odors and Surface-Floating Solids	None	None	Not in objectionable kinds or amounts.	Not of unreasonable kind, quantity or duration.
Temperature	No artificial rise	NHF&GD, NEIWPCC, or NTAC-DI -- whichever provides most effective control. [3]	NHF&GD, NEIWPCC or NTAC-DI -- whichever provides most effective control. [3]	Shall not exceed 90° F.

Note: 1 The waters in each classification shall satisfy all provisions of all lower classifications.
2 For complete details see Chapter 149 RSA.
3 NHF&GD New Hampshire Fish and Game Department
NEIWPCC New England Interstate Water Pollution Control Commission
NTAC-DI National Technical Advisory Committee, Department of the Interior

... the City of Dover, and the Towns of Rollinsford.

With the continuing upgrading of existing waste treatment facilities and construction of new facilities, and the provisions of the new Safe Drinking Water Act, coupled with the requirement of storage for any proposed surface water source of supply, water quality is not expected to be an insurmountable problem as far as a finished product to consumers is concerned. The construction of a reservoir, should a surface supply(s) be chosen, will of course have short term effects on downstream water quality caused by the dam construction, and may also effect the quality over the long term depending on flow regulation by the reservoir. If surface supplies are selected, each site designated would have to be studied to determine any and all environmental and social impacts prior to a final recommendation.

IV. FINDINGS

A. Comparison of Supply and Demand

Based upon the criteria developed for this report it appears that 13 of the 47 study area communities may not have a public water supply system even through the long range target year (2020). These communities would be expected to maintain individual on-lot systems as their supply source.

Table IV-1 lists the communities expected to be served by public water supply systems; their existing safe yields; and, the average and maximum day demands and deficits anticipated for each target year. In the evaluation of the supply-demand relationships shown the maximum day demands are important because communities supplied by groundwater sources only must be able to meet these demands by the estimated safe yields of these sources. This table gives the highest deficit values because it measures future demands against existing systems capabilities. It is included because it establishes a base condition, and demonstrates which communities must initiate immediate action to secure additional sources of water. Obviously, if the communities expected to initiate water systems do not also develop supply sources, their anticipated demands can not be met. Of the communities with existing systems, however, three - Epping, Raymond and Salem - are not expected to meet 1980 average day demands, and an additional ten, for a total of 13 of 17 suppliers, are not expected to meet 1980 maximum day demands without source augmentation.

The total number of existing suppliers unable to meet average day demands without source augmentation increases rather uniformly over the study time period from three by 1980 to 11 by 2020. And, of the 17 existing suppliers, only one - Exeter - is expected to meet its demands throughout the study's time frame if the other suppliers do not secure additional sources. The deficits for existing suppliers as Table IV-1 indicates, rise from approximately 1.4 mgd and 13.9 mgd by 1980, to approximately 10.3 mgd and 45.6 mgd by 2020 for average and maximum days respectively.

Table IV-2 lists all of the information in Table IV-1 plus all of the potential groundwater previously identified in Table III-1 has been added to the existing safe yields of each water supplier. As shown in Table IV-2, if all groundwater considered available were developed, several communities would have adequate supplies until almost 2020. A number of other municipalities however, even with full

TABLE IV-1

EXISTING SAFE YIELDS, DEMANDS AND DEFICITS
FOR COMMUNITIES WITH PUBLIC WATER SUPPLIES

Community	Existing Safe Yield (mgd)	1980				1990				2000				2010				2020			
		Demands		Deficits		Demands		Deficits		Demands		Deficits		Demands		Deficits		Demands		Deficits	
		Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day
Atkinson	0.0	0.30	0.80	0.30	0.80	0.63	1.53	0.63	1.53	0.87	2.02	0.87	2.02	1.08	2.44	1.08	2.44	1.26	2.79	1.26	2.79
Brentwood	0.0	0.0	0.0	0.0	0.0	0.23	0.63	0.23	0.63	0.44	1.12	0.44	1.12	0.69	1.65	0.69	1.65	0.96	2.20	0.96	2.20
Danville	0.0	0.0	0.0	0.0	0.0	0.18	0.51	0.18	0.51	0.28	0.75	0.28	0.75	0.38	0.98	0.38	0.98	0.49	1.23	0.49	1.23
E. Kingston	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	0.66	0.24	0.66	0.38	0.98	0.38	0.98	0.56	1.38	0.56	1.38
Fremont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.36	0.94	0.36	0.94	0.73	1.73	0.73	1.73	1.15	2.57	1.15	2.57
Hampstead	0.0	0.22	0.61	0.22	0.61	0.43	1.09	0.43	1.09	0.62	1.50	0.62	1.50	0.83	1.94	0.83	1.94	1.03	2.34	1.03	2.34
Kensington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28	0.75	0.28	0.75	0.41	1.05	0.41	1.05
Kingston	0.0	0.21	0.59	0.21	0.59	0.36	0.94	0.36	0.94	0.49	1.23	0.49	1.23	0.58	1.42	0.58	1.42	0.62	1.50	0.62	1.50
Newton	0.0	0.20	0.56	0.20	0.56	0.41	1.05	0.41	1.05	0.59	1.44	0.59	1.44	0.76	1.80	0.76	1.80	0.95	2.18	0.95	2.18
Plaistow	0.0	0.36	0.94	0.36	0.94	0.56	1.38	0.56	1.38	0.73	1.73	0.73	1.73	0.89	2.06	0.89	2.06	1.05	2.38	1.05	2.38
S. Hampton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.44	0.15	0.44	0.27	0.73	0.27	0.73	0.42	1.07	0.42	1.07
Stratham	0.0	0.0	0.0	0.0	0.0	0.26	0.71	0.26	0.71	0.55	1.36	0.55	1.36	0.89	2.06	0.89	2.06	1.18	2.63	1.18	2.63
TOTAL	0.0	1.29	3.50	1.29	3.50	3.06	7.84	3.06	7.84	5.32	13.19	5.32	13.19	7.76	18.54	7.76	18.54	10.08	23.32	10.08	23.32
Dover	3.2	3.03	5.98	0.0	2.78	3.60	6.95	0.40	3.75	4.11	7.80	0.91	4.60	4.66	8.70	1.46	5.50	5.09	9.39	1.89	6.19
Durham	1.7	0.95	2.18	0.0	0.48	1.07	2.42	0.0	0.72	1.16	2.59	0.0	0.89	1.49	3.23	0.0	1.53	2.23	4.58	0.53	2.88
Epping	0.09	0.15	0.44	0.06	0.35	0.26	0.71	0.17	0.62	0.44	1.12	0.35	1.03	0.63	1.52	0.54	1.43	0.83	1.94	0.74	1.85
Exeter	4.93	0.91	2.10	0.0	0.0	1.07	2.42	0.0	0.0	1.26	2.79	0.0	0.0	1.40	3.06	0.0	0.0	1.41	3.07	0.0	0.0
Farmington	1.0	0.34	0.89	0.0	0.0	0.39	1.00	0.0	0.0	0.46	1.16	0.0	0.16	0.52	1.29	0.0	0.29	0.57	1.40	0.0	0.40
Greenland	W/Port.	(0.21)	(0.59)	--	--	(0.40)	(1.03)	--	--	(0.64)	(1.55)	--	--	(0.92)	(2.12)	--	--	(1.20)	(2.67)	--	--
Hampton	5.65	2.00	4.60	0.0	0.0	3.32	7.64	0.0	1.99	3.86	8.88	0.0	3.23	4.53	10.42	0.0	4.77	5.08	11.68	0.0	6.03
Milton	0.28	0.12	0.36	0.0	0.08	0.15	0.44	0.0	0.16	0.21	0.59	0.0	0.31	0.26	0.71	0.0	0.43	0.33	0.87	0.05	0.59
New Castle	W/Port.	(0.09)	(0.28)	--	--	(0.11)	(0.71)	--	--	(0.13)	(0.39)	--	--	(0.14)	(0.41)	--	--	(0.14)	(0.41)	--	--
Newfields	0.14	0.05	0.17	0.0	0.03	0.07	0.23	0.0	0.09	0.11	0.33	0.0	0.19	0.18	0.51	0.04	0.37	0.27	0.73	0.13	0.59
Newington	W/Port.	(0.02)	(0.08)	--	--	(0.04)	(0.14)	--	--	(0.06)	(0.20)	--	--	(0.10)	(0.31)	--	--	(0.15)	(0.44)	--	--
New Market	1.50	0.35	0.92	0.0	0.0	0.38	0.98	0.0	0.0	0.41	1.05	0.0	0.0	0.49	1.23	0.0	0.0	0.65	1.57	0.0	0.07
N. Hampton	W/Hamp.	(0.52)	(1.20)	--	--	(0.97)	(2.23)	--	--	(1.37)	(3.15)	--	--	(1.86)	(4.28)	--	--	(2.31)	(5.31)	--	--
Portsmouth	5.30	4.66	8.70	0.0	3.40	5.45	9.97	0.15	4.67	6.37	11.42	1.07	6.12	7.28	12.82	1.98	7.52	7.97	13.87	2.67	8.57
Raymond	0.18	0.21	0.59	0.03	0.41	0.25	0.68	0.07	0.50	0.32	0.85	0.14	0.67	0.40	1.03	0.22	0.85	0.47	1.18	0.29	1.00
Rochester	4.00	2.63	5.29	0.0	1.29	3.03	5.98	0.0	1.98	3.47	6.73	0.0	2.73	3.91	7.47	0.0	3.47	4.38	8.24	0.38	4.24
Rollinsford	0.25	0.14	0.41	0.0	0.16	0.20	0.56	0.0	0.31	0.26	0.71	0.01	0.46	0.34	0.89	0.09	0.64	0.41	1.05	0.16	0.80
Rye	W/Hamp & Port.	(0.49)	(1.37)	--	--	(0.79)	(1.86)	--	--	(1.08)	(2.49)	--	--	(1.34)	(2.94)	--	--	(1.58)	(3.39)	--	--
Salem	1.80	3.08	6.07	1.28	4.27	3.78	7.25	1.98	5.45	4.42	8.31	2.62	6.51	4.68	8.73	2.88	6.93	4.85	9.01	3.05	7.21
Seabrook	1.90	0.89	2.05	0.0	0.15	1.33	3.06	0.0	1.16	1.77	4.07	0.0	2.17	2.11	4.85	0.21	2.95	2.35	4.79	0.45	2.89
Somersworth	3.26	1.67	3.56	0.0	0.30	1.87	3.93	0.0	0.67	2.08	4.31	0.0	1.05	2.35	4.79	0.0	1.53	2.59	5.22	0.0	1.96
Wakefield	0.25	0.16	0.46	0.0	0.21	0.18	0.51	0.0	0.26	0.20	0.56	0.0	0.31	0.21	0.59	0.0	0.34	0.23	0.63	0.0	0.38
TOTAL	35.43	21.34	44.77	1.37	13.91	26.34	54.73	2.77	22.33	30.92	63.27	5.10	30.43	35.44	71.84	7.42	38.55	39.71	79.22	10.34	45.65
GRAND TOTAL	35.43	22.63	48.27	2.66	17.41	29.40	62.57	5.83	30.17	36.24	76.46	10.42	43.62	43.20	90.38	15.18	57.09	49.79	102.54	20.42	68.97

TABLE IV-2

ESTIMATED SAFE YIELDS, DEMANDS AND DEFICITS FOR COMMUNITIES WITH PUBLIC WATER SUPPLIES

Community	Exist Safe Yield (mgd)	Possible Future G. W. (mgd)	Total Safe Yield (mgd)	1980				1990				2000				2010				2020			
				Demands		Deficits		Demands		Deficits		Demands		Deficits		Demands		Deficits		Demands		Deficits	
				Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day	Ave Day	Max Day
Atkinson	0.0	0.0	0.0	0.30	0.80	0.30	0.80	0.63	1.53	0.63	1.53	0.87	2.02	0.87	2.02	1.08	2.44	1.08	2.44	1.26	2.79	1.26	2.79
Brentwood	0.0	1.31	1.31	0.0	0.0	0.0	0.0	0.23	0.63	0.0	0.0	0.44	1.12	0.0	0.0	0.69	1.65	0.0	0.34	0.96	2.20	0.0	0.89
Danville	0.0	0.27	0.27	0.0	0.0	0.0	0.0	0.18	0.51	0.0	0.24	0.28	0.75	0.01	0.48	0.38	0.98	0.11	0.71	0.49	1.23	0.22	0.96
E. Kingston	0.0	0.53	0.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	0.66	0.0	0.13	0.38	0.98	0.0	0.45	0.56	1.38	0.03	0.85
Fremont	0.0	1.08	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.36	0.94	0.0	0.0	0.73	1.73	0.0	0.65	1.15	2.57	0.07	1.49
Hampstead	0.0	0.18	0.18	0.22	0.61	0.04	0.43	0.43	1.09	0.25	0.91	0.62	1.50	0.44	1.32	0.83	1.94	0.65	1.76	1.03	2.34	0.85	2.16
Kensington	0.0	2.02	2.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28	0.75	0.0	0.0	0.41	1.05	0.0	0.0
Kingston	0.0	1.34	1.34	0.21	0.59	0.0	0.0	0.36	0.94	0.0	0.0	0.49	1.23	0.0	0.0	0.58	1.42	0.0	0.08	0.62	1.50	0.0	0.16
Newton	0.0	1.19	1.19	0.20	0.56	0.0	0.0	0.41	1.05	0.0	0.0	0.59	1.44	0.0	0.25	0.76	1.80	0.0	0.61	0.95	2.18	0.0	0.99
Plaistow	0.0	1.64	1.64	0.36	0.94	0.0	0.0	0.56	1.38	0.0	0.0	0.73	1.73	0.0	0.09	0.89	2.06	0.0	0.42	1.05	2.38	0.0	0.74
S. Hampton	0.0	0.26	0.26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.44	0.0	0.18	0.27	0.73	0.01	0.47	0.42	1.07	0.16	0.81
Stratham	0.0	1.50	1.50	0.0	0.0	0.0	0.0	0.26	0.71	0.0	0.0	0.55	1.36	0.0	0.0	0.89	2.06	0.0	0.56	1.18	2.63	0.0	1.13
TOTAL	0.0	11.32	11.32	1.29	3.50	0.34	1.23	3.05	7.84	0.88	2.68	5.31	13.19	1.32	4.47	7.78	18.54	1.85	8.49	10.08	23.32	2.59	12.97
Dover	3.2	2.5	5.7	3.03	5.98	0.0	0.28	3.60	6.95	0.0	1.25	4.11	7.80	0.0	2.10	4.66	8.70	0.0	3.00	5.09	9.39	0.0	3.69
Durham	1.7	0.0	1.7	0.95	2.18	0.0	0.48	1.07	2.42	0.0	0.72	1.16	2.59	0.0	0.89	1.49	3.23	0.0	1.53	2.23	4.58	0.53	2.88
Epping	0.09	0.8	0.89	0.15	0.44	0.0	0.0	0.26	0.71	0.0	0.0	0.44	1.12	0.0	0.23	0.63	1.52	0.0	0.63	0.83	1.94	0.0	1.05
Exeter	4.93	0.0	4.93	0.91	2.10	0.0	0.0	1.07	2.42	0.0	0.0	1.26	2.79	0.0	0.0	1.40	3.06	0.0	0.0	1.41	3.07	0.0	0.0
Farmington	1.0	3.25	4.25	0.34	0.89	0.0	0.0	0.39	1.00	0.0	0.0	0.46	1.16	0.0	0.0	0.52	1.29	0.0	0.0	0.57	1.40	0.0	0.0
Greenland	W/Portsmouth			(0.21)	(0.59)	-	-	(0.40)	(1.03)	-	-	(0.64)	(1.55)	-	-	(0.92)	(2.12)	-	-	(1.20)	(2.67)	-	-
Hampton	5.65	2.15	7.80	2.00	4.60	0.0	0.0	3.32	7.64	0.0	0.0	3.86	8.88	0.0	1.08	4.53	10.42	0.0	2.62	5.08	11.68	0.0	3.88
Milton	0.28	0.56	0.84	0.12	0.36	0.0	0.0	0.15	0.44	0.0	0.0	0.21	0.59	0.0	0.0	0.26	0.71	0.0	0.0	0.33	0.87	0.0	0.03
New Castle	W/Portsmouth			(0.09)	(0.28)	-	-	(0.11)	(0.71)	-	-	(0.13)	(0.39)	-	-	(0.14)	(0.41)	-	-	(0.14)	(0.41)	-	-
Newfields	0.14	0.60	0.74	0.05	0.17	0.0	0.0	0.07	0.23	0.0	0.0	0.11	0.33	0.0	0.0	0.18	0.51	0.0	0.0	0.27	0.73	0.0	0.0
Newington	W/Portsmouth			(0.02)	(0.08)	-	-	(0.04)	(0.14)	-	-	(0.06)	(0.20)	-	-	(0.10)	(0.31)	-	-	(0.15)	(0.44)	-	-
New Market	1.50	0.60	2.10	0.35	0.92	0.0	0.0	0.38	0.98	0.0	0.0	0.41	1.05	0.0	0.0	0.49	1.23	0.0	0.0	0.65	1.57	0.0	0.0
N. Hampton		W/Hampton		(0.52)	(1.20)	-	-	(0.97)	(2.23)	-	-	(1.37)	(3.15)	-	-	(1.86)	(4.28)	-	-	(2.31)	(5.31)	-	-
Portsmouth	5.30	0.60	5.90	4.66	8.70	0.0	2.8	5.45	9.97	0.0	4.07	6.37	11.42	0.47	5.52	7.28	12.82	1.38	6.92	7.97	13.87	2.07	7.97
Raymond	0.18	0.0	0.18	0.21	0.59	0.03	0.41	0.25	0.68	0.07	0.50	0.32	0.85	0.14	0.67	0.40	1.03	0.22	0.85	0.47	1.18	0.29	1.00
Rochester	4.00	3.94	7.94	2.63	5.29	0.0	0.0	3.03	5.98	0.0	0.0	3.47	6.73	0.0	0.0	3.91	7.47	0.0	0.0	4.38	8.24	0.0	0.30
Rollinsford	0.25	0.0	0.25	0.14	0.41	0.0	0.16	0.20	0.56	0.0	0.31	0.26	0.71	0.01	0.46	0.34	0.89	0.09	0.64	0.41	1.05	0.16	0.80
Rye	W/Hampton & Portsmouth			(0.49)	(1.37)	-	-	(0.79)	(1.86)	-	-	(1.08)	(2.49)	-	-	(1.34)	(2.94)	-	-	(1.58)	(3.39)	-	-
Salem	1.80	0.14	1.94	3.08	6.07	1.14	4.13	3.78	7.25	1.84	5.31	4.42	8.31	2.48	6.37	4.68	8.73	2.74	6.79	4.85	9.01	2.91	7.06
Seabrook	1.90	0.0	1.90	0.89	2.05	0.0	0.15	1.33	3.06	0.0	1.16	1.77	4.07	0.0	2.17	2.11	4.85	0.21	2.95	2.35	4.79	0.45	2.89
Somersworth	3.26	0.0	3.26	1.67	3.56	0.0	0.30	1.87	3.93	0.0	0.67	2.08	4.31	0.0	1.05	2.35	4.79	0.0	1.53	2.59	5.22	0.0	1.96
Wakefield	0.25	2.08	2.33	0.16	0.46	0.0	0.0	0.18	0.51	0.0	0.0	0.20	0.56	0.0	0.0	0.21	0.59	0.0	0.0	0.23	0.63	0.0	0.0
TOTAL	35.43	17.22	52.65	21.34	44.77	1.17	8.71	26.34	54.73	1.91	13.99	30.92	63.27	3.10	20.54	35.44	71.84	4.64	27.46	39.71	79.22	6.41	33.51
GRAND TOTAL	35.43	28.54	63.97	22.63	48.27	1.51	9.94	29.39	62.57	2.79	16.67	36.23	76.46	4.42	25.01	43.22	90.38	6.49	35.95	49.79	102.54	9.00	46.48

development of their groundwater resources would require augmentation by other sources. For example, Atkinson and Hampstead may exceed their locally available resources by 1980 and by the year 2000 the majority of towns would have difficulty meeting maximum day requirements.

The safe yields of the twelve communities which have been assumed to initiate public water supply systems are taken directly from Table III-1 which lists the expected available groundwater sources for the communities within the study area.

The communities which have existing systems present a more complex picture than those without systems because current draws on the groundwater aquifer may not correspond to political boundaries. Industries have also tapped some of these resources, which further clouds the picture. Therefore, the possible future groundwater listed for the communities with existing systems, represents the results of accounting for all known existing users, locations of use and the amount of withdrawals subtracted from the estimated resource. The following listing of communities presents the background information for how each of the community groundwater estimates were arrived at.

1. Dover - The 2.5 mgd reported available assumes that the "Hoppers" area of the town can support the 3.0 mgd estimated by the town's consulting engineer. The accuracy of this estimate will dictate the magnitude of Dover's deficit, because its not expected even with this additional groundwater, to be able to meet the maximum demands of 1980.

2. Durham - Uses the Lamprey and Oyster Rivers for supply, no groundwater reported available. Unless storage is increased, Durham is not expected to meet its 1980 maximum day demand.

3. Epping - It is estimated that an additional 0.80 mgd could be obtained from approximately 4 more wells. This would allow Epping to meet its needs until about the year 2000.

4. Exeter - Presently uses a combination of surface and groundwater sources with a safe yield of 4.93 mgd. The reported safe yield of its wells - 1.66 mgd - is greater than the potential estimated by this report; therefore, no additional groundwater source is considered available. Based on the estimated future demands it appears Exeter should have adequate supplies to meet its long term needs.

5. Farmington - If the aquifer straddling the Cocheco River is as large as estimated, Farmington could have an additional 3.25 mgd of groundwater which is over 2 times greater than the estimated 2020 maximum day demand. Therefore, Farmington appears to have adequate sources, if developed, to meet its demands. Full pumping of the aquifer may impact on the Cocheco's low flows, however, the severity of this impact, should it occur, is beyond the scope of the report.

6. Greenland - Supplied by Portsmouth which has tapped both areas of significant groundwater within the community. An additional well or wells in one area may be able to complete development of one aquifer and that is where the additional 0.6 mgd shown for Portsmouth orginates.

7. Hampton - The total estimated safe yields of the aquifers in Hampton, North Hampton and Rye are 7.80 mgd. Because the Hampton Water Works has wells in these three communities already, it has been assumed that it will fully develop these aquifers, therefore, an additional 2.15 mgd over their present estimated safe yield of 5.65 mgd has been considered available. Even with this additional supply, it is not anticipated that the Hampton Water Works will be able to meet its estimated 2000 maximum day demand.

8. Milton - Has developed 0.28 mgd of a total estimated resource of 0.84 mgd, therefore 0.56 mgd additional supply has been allocated to this community. This additional supply is estimated to allow Milton to meet all demands within the study's time frame except for the 2020 maximum day demand.

9. New Castle - An island supplied by Portsmouth reportedly without the resources to develop a source of its own.

10. Newfields - It is estimated that a total of 0.82 mgd of groundwater is available within the community. The town has developed 0.14 mgd of this with 2 wells and an industry has located one well in the same general area, therefore about 0.60 mgd is estimated to be available for the town's further development. Full development of this resource will allow the community to meet all of its estimated needs throughout the study's time frame.

11. Newington - Served by Portsmouth. Its groundwater aquifer is located beneath Pease Air Force Base, and to compensate Portsmouth for the loss of this source of supply the Bellamy Reservoir and Treatment Plant was constructed in Madbury.

12. Newmarket - Presently uses a combination of surface and groundwater sources. An estimated 1.2 mgd of groundwater is available of which approximately half has been developed. Full development of this resource could allow Newmarket to meet its estimated demands throughout the study's time frame.

13. North Hampton - Served by Hampton and discussed under Hampton.

14. Portsmouth - Estimated to be able to develop an additional 0.60 mgd in Greenland; however, even with this development and its existing reservoir, it may have difficulty meeting the system's 1980 maximum day demand.

15. Raymond - No groundwater available, therefore its existing safe yield of 0.18 mgd assumed maximum developable. It is not expected that Raymond will be able to meet its 1980 maximum day demand, or any average day demands after 1980.

16. Rochester - Uses surface water exclusively, however, the aquifer along the Cocheco River extends into Rochester and is estimated at 3.94 mgd safe yield within Rochester. Full development of this aquifer may impact on the low flows of the Cocheco. Full development of this aquifer would allow Rochester to meet its estimated 2020 maximum day demand depending on available storage.

17. Rollinsford - No groundwater available, therefore its existing safe yield of 0.25 mgd is assumed to be the maximum developable. It is not expected that Rollinsford will be able to meet its 1980 maximum day demand.

18. Rye - Previously discussed under Hampton above, it is served by both the Hampton Water Works and the City of Portsmouth.

19. Salem - Uses surface water supply exclusively. A small amount of groundwater may be available, however Salem will probably have difficulty meeting 1980 average day demands.

20. Seabrook - The estimated safe yield of the groundwater sources by this report for Seabrook is 1.2 mgd; Seabrook reports a capacity of 1.9 mgd, therefore it has been assumed that all groundwater sources have been fully developed. It is not anticipated that Seabrook will be able to meet its 1980 maximum day demands.

21. Somersworth - Presently draws approximately 2.3 mgd from an aquifer rated at approximately 6.2 mgd safe yield. The City of Dover draws approximately 1.8 mgd from this aquifer, and at least one industry has a well in this aquifer also. Therefore, it has been assumed that all groundwater has been developed. Somersworth is not expected to be able to meet its 1980 maximum day demands.

22. Wakefield - Presently can draw 0.25 mgd from an aquifer rated at approximately 0.35 mgd. Most of its future groundwater resources are located around Pine River Pond and may not be able to be developed.

B. Discussion

As discussed in the previous paragraphs the possible development of additional groundwater resources could allow a number of communities to meet portions of their future water supply demands. How long these local resources can serve the communities depends on the actual quantity and quality of the supply. The estimates shown in this report were drawn from available data and would be subject to revisions with field data.

A major assumption made with regard to the groundwater is that the full reported potential can be developed. A variance from this assumption would significantly alter the capability of many communities to meet their future needs. For example, if only one-half of the reported potential could be developed, the region as a whole would face a short term (1980-1990) supply shortage unless other resources were developed either through in-basin surface water reservoirs or inter-basin transfers.

Table IV-2 illustrates, moreover, that even if all of the groundwater assumed available is developed by the individual communities, water shortages are anticipated in several of these communities by 1980. Of the 34 communities within the study area which either have or are expected to initiate public water supply systems, 29 will require source augmentation by the year 2020, and of these 29, 14 were estimated to require this augmentation by the year 1980.

Based upon the above information the following conclusions can be drawn:

1. The latest population estimates prepared for the region differ markedly from those used in the earlier Statewide Water Supply Study. As a result, water supply demands estimated for the region are less than those indicated by the statewide study.

2. Available data on present suppliers was limited in some communities. Future demand estimates in some cases therefore, relied upon pooled data.

3. Conservation measures such as use of water saving toilets and shower heads in new or replacement homes appear to offer an effective method of reducing overall increases in water demand.

4. Comparisons between future supply estimates and currently available safe yield highlight a need for additional resource development within the region. Overall, without new supply sources a number of communities in the near future will face water shortages.

5. Both ground and surface water resources appear available if developed to aid in meeting the region's future supply needs.

6. Water quality as it relates to future drinking water resources varies within the region. Groundwater sources in some cases are affected by high iron content while surface streams are subject to waste discharges.

7. Deficits shown in Table IV-2 indicate that even with the development of the region's groundwater resources additional supply development will be necessary if the estimated future needs are to be met.

8. Development of any major industrial complex such as an oil refinery should be planned with attention to the capability of the supporting natural resources.

9. Alternative supply plans developed in the future should include evaluations of the potential social, economic, legal and environmental effects of the plans.

APPENDIX I

APPENDIX I - DEMAND PROGRAM

To facilitate the computations involved in determining the future domestic and industrial demands of the study area, a computer program has been developed. Specifically, the program performs the following computations:

1. It generates two sets of future gallon per capita per day rates for domestic water usage. One is a straight line relationship between time (in years) and the GPCD rate itself. The second generates GPCD rates based upon time, the number of people served and the product, or interaction, of time and the number of people served.

2. It generates community's densities for each of the 5 target years - 1980, 1990, 2000, 2010, and 2020.

3. It generates the percent served/density relationship.

4. It generates the percent population served, number for each community based upon that community's density for each of the 5 target years.

5. It calculates the number of people served in a community for each of the 5 target years.

6. It calculates the future industrial demand, for each community presently serving an industry, for each of the 5 target years.

7. It generates when, and if, a community, not now served, will be served, and the domestic demand expected of that community by both GPCD rates.

The input required to obtain the above output is:

a. The existing domestic gallon per capita per day rates per community per year.

b. The existing served population per community per year.

c. Community name, adjusted gross acreage (total area minus inland water bodies and State and National Parks/Forests), plus estimated future population per community per target year.

d. The existing densities and percent community population served data.

e. The industrial water use ratio, per SIC Code per target year.

f. Existing industrial demands, aggregated per SIC Code per community.

g. Communities with existing water supply systems, their estimated future served populations and future domestic GPCD rates.

A copy of the Computer program is listed below for reference.

```
// JOB    2101

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        2101        2101        0001
                          00A8        0000

V2 M11   ACTUAL 16K   CONFIG 16K

// FOR
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
*IOCS(TYPEWRITER,1132 PRINTER,KEYBOARD,DISK,CARD)
      DIMENSION SUMI(80), NSIC(80),HQ80(50),HQ90(50),HQ00(50),HQ10(50),
     1HQ20(50),TSUMI(20,10),LF(50),TISUM(10)
      DIMENSION GPCD(16,13),AGPCD(50), POP(16,13),APOP(50), X(1,14),
     1AC(50),POP80(50),POP90(50),POP00(50),POP10(50),POP20(50),DEN80(50)
     2,DEN90(50),DEN00(50),DEN10(50),DEN20(50),PC(50),DEN(50),TPC80(50),
     3TPC90(50),TPC00(50),TPC10(50),TPC20(50),SP80(50),SP90(50),SP00(50)
     4,SP10(50),SP20(50),TPPD(4,4),VAR(13,4),YDIF(50),YSQ(50),CLPC(30)
      DIMENSION B(4,1),SICF(10,5),IND(10),GI(500),FIUG(20,10),IWS(50),
     1VTP(4,13),JI(4),JJ(4),VART(4,13),TPP(4,4),Y(13,1),TWN(50,4),
     2GPCDL(5),DQ80(50),DQ90(50),DQ00(50),DQ10(50),DQ20(50),CLDEN(30)
      READ(2,10)NX,NO,K,L,M,ITNO
   10 FORMAT(6I5)
C     AVERAGE EXISTING GPCD CALC FOR REGION PER YEAR
      DO 101 I =1,NO
  101 READ(2,102)(GPCD(I,J),J=1,NX)
  102 FORMAT(13F6.1)
      DO 120 J = 1,NX
      SUMG = 0.0
      IC = 0
      DO 100 I = 1,NO
      IF(GPCD(I,J)-0.)100,100,110
  110 IC = IC + 1
      SUMG = SUMG + GPCD(I,J)
  100 CONTINUE
      AGPCD(J)=SUMG/IC
  120 CONTINUE
C   AVERAGE SERVED POP PER REGION PER YEAR (EXISTING)
      DO 131 I = 1,NO
  131 READ(2,132)(POP(I,J),J=1,NX)
  132 FORMAT(13F6.1)
      DO 140 J = 1,NX
      IC = 0
      SUMP = 0.0
      DO 130 I = 1,NO
      IF(POP(I,J)-0.)130,130,136
  136 IC = IC + 1
      SUMP=SUMP+POP(I,J)
  130 CONTINUE
      APOP(J)=SUMP/IC
  140 CONTINUE
C     FORECAST DOMESTIC USAGE RATES
C     REGIONAL FORECAST   STRAIGHT LINE   USED FOR NEW SYSTEMS
      DO 150 I = 1,M
  150 READ(2,151)(X(I,J),J=1,13)
  151 FORMAT(13F6.1)
      SUMX = 0.0
      SUMXX = 0.0
      SUMXY = 0.0
      SUMY = 0.0
```

```
      DO 200 I=1,M
      DO 200 J=1,NX
      SUMX=SUMX+X(I,J)
      SUMXX=SUMXX+X(I,J)*X(I,J)
      SUMXY=SUMXY+X(I,J)*AGPCD(J)
      SUMY = SUMY + AGPCD(J)
  200 CONTINUE
      B1 = (SUMXY-(SUMX*SUMY/NX))/(SUMXX-(SUMX*SUMX/NX))
      B0 = SUMY/NX - B1*(SUMX/NX)
      WRITE(3,202)
  202 FORMAT(1H1,9X,62HSTRAIGHT LINE RELATIONSHIP BETWEEN YEARS AND GPCD
     1 RATES YIELDS,/)
      WRITE(3,201)B0,B1
  201 FORMAT(//,10X,20HESTIMATES OF B'S ARE,5X 5HB0 = ,F10.4,5X,5HB1 = ,
     1F10.4,//)
      X1 = 21.0
      DO 210 I = 1,5
      FGPCD=B0+B1*X1
      GPCDL(I) = FGPCD
      X2=1959.0+X1
      WRITE(3,211)FGPCD,X2
  211 FORMAT(10X,18HFORECASTED GPCD = , F10.2,5X,10HAT YEAR = ,F10.1)
      X1 = X1 + 10.0
  210 CONTINUE
C    CALCULATE GPCD RATES BASED ON POP SERVED AND YEAR (1959 = 1)
C     SET VARIABLE MATRIX
      DO 400 I = 1,NX
  400 VAR(I,1) = 1.0
      DO 401 I = 1,NX
  401 VAR(I,2) = X(1,I)
      DO 402 I = 1,NX
  402 VAR(I,3) = APOP(I)
      DO 403 I =1,NX
  403 VAR(I,4)= APOP(I) *  X(1,I)
      DO 411 I = 1,NX
  411  Y(I,1) = AGPCD(I)
      CALL GMTRA(VAR,VART,NX,K)
      CALL GMPRD(VART,VAR,TPP,K,NX,K)
      CALL MINV(TPP,K,TPPD,JI,JJ)
      CALL GMPRD(TPP,VART,VTP,K,K,NX)
      CALL GMPRD(VTP,Y,B,K,L,M)
      WRITE(3,444)
  444 FORMAT(//,23X,35HMULTIPLE LINEAR REGRESSION ANALYSIS)
      WRITE(3,445)
  445 FORMAT(/,5X,70HGPCD RATES REGRESSED ON YEARS, POPULATION SERVED AN
     1D THEIR INTERACTION)
      WRITE(3,417)
  417 FORMAT(//,30X,20HESTIMATES OF B'S ARE)
      DO 415 I = 1,4
  415 WRITE(3,416) B(I,M)
  416 FORMAT(/,30X,4HB = ,E12.4)
      B00 = B(1,1)
      B11 = B(2,1)
      B22 = B(3,1)
      B33 = B(4,1)
      SUMY = 0.0
      DO 420 I = 1,NX
  420 SUMY = SUMY + Y(I,M)
      YBAR = SUMY/NX
      SUMSQ = 0.0
```

```
      DO 430 I =1,NX
      YDIF(I) = Y(I,M)-YBAR
      YSQ(I) = YDIF(I)*YDIF(I)
  430 SUMSQ = SUMSQ + YSQ(I)
      IDF = L - K
      SIGSQ = SUMSQ/IDF
      VB0 = TPP(1,1)*SIGSQ
      SEB0 = VB0**0.5
      VB1 = TPP(2,2)*SIGSQ
      SEB1 = VB1**0.5
      VB2 = TPP(3,3)*SIGSQ
      SEB2 = VB2**0.5
      VB3 = TPP(4,4)*SIGSQ
      SEB3 = VB3**0.5
      WRITE(3,435)
  435 FORMAT(//,17X,46HTHE VARIANCE AND STANDARD ERROR OF THE B'S ARE)
      WRITE(3,436)VB0,VB1,VB2,VB3
  436 FORMAT(//,3X,6HVB0 = ,F10.6,2X,6HVB1 = ,F10.6,2X,6HVB2 = ,F12.8,
     12X,6HVB3 = ,F12.8)
      WRITE(3,437)SEB0,SEB1,SEB2,SEB3
  437 FORMAT(//,3X,7HSEB0 = ,F10.6,1X,7HSEB1 = ,F10.6,1X,7HSEB2 = ,
     1F12.8,1X,7HSEB3 = ,F12.8)
C  ADJUSTED, GROSS DENSITY CALCULATIONS
C     ADJUSTED MEANS INLAND WATER AREAS AND PUBLIC LANDS SUBTRACTED
      DO 300 I=1,ITNO
  300 READ(2,301)(TWN(I,J),J=1,4),AC(I),POP.0(I),POP90(I),POP00(I),POP10
     1(I),POP20(I)
  301 FORMAT(4A4,6F10.4)
      WRITE(3,316)
  316 FORMAT(1H1,22X,36HTOWN AND FORECASTED DENSITY, BY YEAR)
      WRITE(3,317)
  317 FORMAT(//,10X,4HTOWN,14X,4H1980,8X,4H1990,8X,4H2000,8X,4H2010,8X,
     14H2020,/)
      DO 310 I = 1,ITNO
      DEN80(I) = POP80(I)/AC(I)
      DEN90(I) = POP90(I)/AC(I)
      DEN00(I) = POP00(I)/AC(I)
      DEN10(I) = POP10(I)/AC(I)
      DEN20(I) = POP20(I)/AC(I)
  310 WRITE(3,305)(TWN(I,J),J=1,4),DEN80(I),DEN90(I),DEN00(I),DEN10(I),D
     1EN20(I)
  305 FORMAT(5X,4A4,5(2X,F10.4))
C   REGRESS EXISTING DENSITIES ON POP SERVED  INPUT AVE DENSITIES
C  AND PERCENT SERVED FOR DENSITIES LESS THAN ONE
      DO 306 I = 1,9
  306 READ(2,303)PC(I),DEN(I)
  303 FORMAT(2F10.4)
      SUMPC = 0.0
      SUMDN = 0.0
      SUMPD = 0.0
      SUMD2 = 0.0
      DO 315 I = 1,9
      CLPC(I) = (ALOG(PC(I)))/2.303
      CLDEN(I) = (ALOG(DEN(I)))/2.303
      SUMPC = SUMPC + CLPC(I)
      SUMDN = SUMDN + CLDEN(I)
      SUMPD = SUMPD + CLPC(I) * CLDEN(I)
      SUMD2 = SUMD2 +   CLDEN(I) * CLDEN(I)
  315 CONTINUE
        FAC =  9.0/SUMDN
```

```
      B1 = (SUMPC -    (FAC*SUMPD))/(SUMDN -    (FAC * SUMD2))
      CLBO = (SUMPC - (B1 * SUMDN))/9.0
      BO = 10.0**CLBO
      WRITE(3,321)
  321 FORMAT(1H1,15X,50HDENSITY AND PERCENT POPULATION SERVED RELATIONSH
     1IP)
      WRITE(3,322)
  322 FORMAT(//,20X,40HMODEL USED- P.C. SERVED = BO*DENSITY**B1,/)
      WRITE(3,320)BO,B1
  320 FORMAT(23X,5HBO = ,F10.4,5X,5HB1 = ,F10.4)
      WRITE(3,323)
  323 FORMAT(//,7X,74HESTIMATED PERCENT POPULATION SERVED, BY DENSITY RE
     1LATION, BY TOWN, BY YEAR)
      WRITE(3,317)
      DO 350 I = 1,ITNO
      TPC80(I) = BO*DEN80(I)**B1
      TPC90(I) = BO*DEN90(I)**B1
      TPC00(I) = BO*DEN00(I)**B1
      TPC10(I) = BO*DEN10(I)**B1
      TPC20(I) = BO*DEN20(I)**B1
      WRITE(3,305)(TWN(I,J),J=1,4),TPC80(I),TPC90(I),TPC00(I),TPC10(I),T
     1PC20(I)
      SP80(I) = TPC80(I)*POP80(I)*0.01
      SP90(I) = TPC90(I)*POP90(I)*0.01
      SP00(I) = TPC00(I)*POP00(I)*0.01
      SP10(I) = TPC10(I)*POP10(I)*0.01
      SP20(I) = TPC20(I)*POP20(I)*0.01
  350 CONTINUE
      WRITE(3,360)
  360 FORMAT(1H1,22X,34HTOWN AND POPULATION SERVED BY YEAR)
      WRITE(3,361)
  361 FORMAT(/,22X,36H(BASED ON DENSITY RELATIONSHIP ONLY))
      WRITE(3,317)
      DO 370 I = 1,ITNO
  370  WRITE(3,375)(TWN(I,J),J=1,4),SP80(I),SP90(I),SP00(I),SP10(I),SP20
     1(I)
  375 FORMAT(5X,4A4,5(2X,F10.1))
C     FORECAST INDUSTRIAL USAGE
      DO 501 I = 1,10
  501 READ(2,500)(SICF(I,J),J=1,5)
  500 FORMAT(5F10.4)
C    SIC FACTORS ARE ENTERED BY CODE BY YEAR, FROM 1980 ON
C     TOTALIZE INDUSTRIAL DEMANDS BY CODE, USE 0.0 FOR NO DEMAND
      WRITE(3,550)
  550 FORMAT(1H1,22X,35HESTIMATED FUTURE INDUSTRIAL DEMANDS,//)
       DO 522 IJ = 1,10
      DO 522 JK = 1,5
  522 TSUMI(IJ,JK) = 0.0
      DO 520 I = 1,ITNO
      READ(2,510)(TWN(I,J),J=1,4),IND(I)
  510 FORMAT(4A4,I4)
      IF(IND(I)-0)520,520,515
  515 DO 514 IJ = 1,10
  514 READ(2,525)GI(IJ),NSIC(IJ)
  525 FORMAT(F10.2,I2)
      DO 540 JK = 1,5
  540 SUMI(JK) = 0.0
      WRITE(3,530)
  530 FORMAT(//,8X,4HTOWN,9X, 8HSIC CODE,5X,4H1980,6X,4H1990,6X,4H2000,
     16X,4H2010,6X,4H2020,/)
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```
      DO 519 IJ = 1,10
      DO 518 JK = 1,5
      FIUG(IJ,JK) = GI(IJ) * SICF(IJ,JK)
      SUMI(JK) = SUMI(JK) + FIUG(IJ,JK)
      TSUMI(IJ,JK) = TSUMI(IJ,JK) + FIUG(IJ,JK)
  518 CONTINUE
  519 WRITE(3,511)(TWN(I,J),J=1,4),NSIC(IJ),(FIUG(IJ,JK),JK=1,5)
  511   FORMAT(4X,4A4,4X,I2,4X,5F10.1)
      WRITE(3,536)(SUMI(JK),JK=1,5)
  536 FORMAT(/,7X,6HTOTALS,17X,5F10.1)
  520 CONTINUE
      DO 554 JK = 1,5
  554 TISUM(JK) = 0.0
      DO 555 IJ = 1,10
      DO 555 JK = 1,5
  555 TISUM(JK) = TISUM(JK) + TSUMI(IJ,JK)
  524 WRITE(3,523)(TISUM(JK),JK=1,5)
  523 FORMAT(//,5X,25HTOTAL INDUSTRIAL USAGE = ,5F10.1)
      SUM80 = 0.0
      SUM90 = 0.0
      SUM00 = 0.0
      SUM10 = 0.0
      SUM20 = 0.0
      WRITE(3,602)
  602 FORMAT(1H1,15X,50HFUTURE SUPPLIED DOMESTIC DEMANDS, BY TOWN, BY YE
     1AR)
      WRITE(3,603)
  603 FORMAT(/,22X,37H(MULTIPLE LINEAR REGRESSION ANALYSIS))
      WRITE(3,317)
      DO 600 I = 1,ITNO
      READ(2,510)(TWN(I,J),J=1,4),IWS(I)
      IF(IWS(I))635,620,621
  621 READ(2,622)ESP80,ESP90,ESP00,ESP10,ESP20,LF(I)
  622 FORMAT(5F10.4,I2)
      SP80(I) = ESP80
      SP90(I) = ESP90
      SP00(I) = ESP00
      SP10(I) = ESP10
      SP20(I) = ESP20
      IF(LF(I))635,619,623
  619 READ(2,636)YR1,YR2,YR3,YR4,YR5,B0,B1,B2,B3
  636 FORMAT(5F6.1,2F10.4,2F12.8)
      DQ80(I) = (B0+(B1*YR1)+(B2*SP80(I))+((B3*YR1)*SP80(I)))*SP80(I)
      DQ90(I) = (B0+(B1*YR2)+(B2*SP90(I))+((B3*YR2)*SP90(I)))*SP90(I)
      DQ00(I) = (B0+(B1*YR3)+(B2*SP00(I))+((B3*YR3)*SP00(I)))*SP00(I)
      DQ10(I) = (B0+(B1*YR4)+(B2*SP10(I))+((B3*YR4)*SP10(I)))*SP10(I)
      DQ20(I) = (B0+(B1*YR5)+(B2*SP20(I))+((B3*YR5)*SP20(I)))*SP20(I)
      GO TO 666
  623 READ(2,500)GPCD1,GPCD2,GPCD3,GPCD4,GPCD5
      DQ80(I) = SP80(I) * GPCD1
      DQ90(I) = SP90(I) * GPCD2
      DQ00(I) = SP00(I) * GPCD3
      DQ10(I) = SP10(I) * GPCD4
      DQ20(I) = SP20(I) * GPCD5
      GO TO 666
  620 IF(DEN80(I)-0.34)630,635,635
  635 YR = 1.0
      DQ80(I) = (B00+(B11*YR)+(B22*SP80(I))+((B33*YR)*SP80(I)))*SP80(I)
  641 YR = 11.0
      DQ90(I) = (B00+(B11*YR)+(B22*SP90(I))+((B33*YR)*SP90(I)))*SP90(I)
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```
  642 YR = 21.0
      DQ00(I) = (B00+(B11*YR)+(B22*SP00(I))+((B33*YR)*SP00(I)))*SP00(I)
  643 YR = 31.0
      DQ10(I) = (B00+(B11*YR)+(B22*SP10(I))+((B33*YR)*SP10(I)))*SP10(I)
  644 YR = 41.0
      DQ20(I) = (B00+(B11*YR)+(B22*SP20(I))+((B33*YR)*SP20(I)))*SP20(I)
      GO TO 666
  630 DQ80(I) = 0.0
      IF(DEN90(I)-0.34)650,641,641
  650 DQ80(I) = 0.0
      DQ90(I) = 0.0
      IF(DEN00(I)-0.34)660,642,642
  660 DQ80(I) = 0.0
      DQ90(I) = 0.0
      DQ00(I) = 0.0
      IF(DEN10(I)-0.34)670,643,643
  670 DQ80(I) = 0.0
      DQ90(I) = 0.0
      DQ00(I) = 0.0
      DQ10(I) = 0.0
      IF(DEN20(I)-0.34)600,644,644
  666 WRITE(3,375)(TWN(I,J),J=1,4),DQ80(I),DQ90(I),DQ00(I),DQ10(I),DQ20(
     1I)
  600 CONTINUE
      DO 680 I = 1,ITNO
      SUM80 = SUM80 + DQ80(I)
      SUM90 = SUM90 + DQ90(I)
      SUM00 = SUM00 + DQ00(I)
      SUM10 = SUM10 + DQ10(I)
       SUM20 = SUM20 + DQ20(I)
  680 CONTINUE
      WRITE(3,681)SUM80,SUM90,SUM00,SUM10,SUM20
  681 FORMAT(/,8X,6HTOTALS,7X,5F12.1)
      SUM80 = 0.0
      SUM90 = 0.0
      SUM00 = 0.0
      SUM10 = 0.0
      SUM20 = 0.0
      WRITE(3,602)
      WRITE(3,701)
  701 FORMAT(/,26X,28H(STRAIGHT LINE RELATIONSHIP))
      WRITE(3,317)
      DO 700 I = 1,ITNO
      IF(IWS(I))703,715,703
  715 IF(DEN80(I)-0.34)725,703,703
  725 HQ80(I) = 0.0
      IF(DEN90(I)-0.34)730,704,704
  730 HQ80(I) =0.0
      HQ90(I) = 0.0
      IF(DEN00(I)-0.34)735,705,705
  735 HQ80(I) = 0.0
      HQ90(I) = 0.0
      HQ00(I) = 0.0
      IF(DEN10(I)-0.34)740,706,706
  740 HQ80(I) = 0.0
      HQ90(I) = 0.0
      HQ00(I) = 0.0
      HQ10(I) = 0.0
      IF(DEN20(I)-0.34)745,707,707
  745 HQ80(I) = 0.0
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      HQ90(I) = 0.0
      HQ00(I) = 0.0
      HQ10(I) = 0.0
      HQ20(I) = 0.0
      GO TO 700
  703 HQ80(I) = SP80(I) * GPCDL(1)
  704 HQ90(I) = SP90(I) * GPCDL(2)
  705 HQ00(I) = SP00(I) * GPCDL(3)
  706 HQ10(I) = SP10(I) * GPCDL(4)
  707 HQ20(I) = SP20(I) * GPCDL(5)
      WRITE(3,375)(TWN(I,J),J=1,4),HQ80(I),HQ90(I),HQ00(I),HQ10(I),HQ20(
     1I)
  700 CONTINUE
      DO 750 I = 1,ITNO
      SUM80 = SUM80 + HQ80(I)
      SUM90 = SUM90 + HQ90(I)
      SUM00 = SUM00 + HQ00(I)
      SUM10 = SUM10 + HQ10(I)
      SUM20 = SUM20 + HQ20(I)
  750 CONTINUE
      WRITE(3,681)SUM80,SUM90,SUM00,SUM10,SUM20
      CALL EXIT
      END

UNREFERENCED STATEMENTS
 524

FEATURES SUPPORTED
 ONE WORD INTEGERS
 IOCS

CORE REQUIREMENTS FOR
 COMMON      0  VARIABLES   7912  PROGRAM   3876

END OF COMPILATION

// XEQ
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